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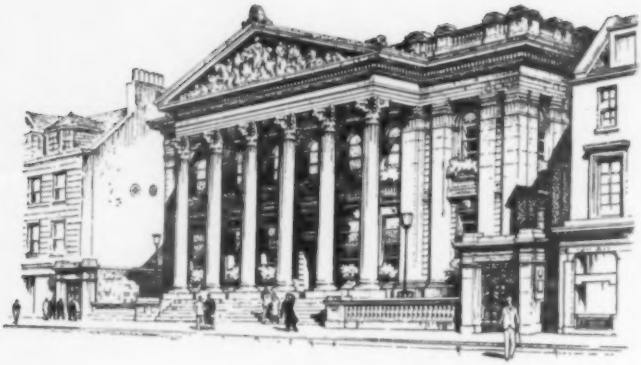

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THE GLACIATION OF NORTH-EAST SCOTLAND

F. M. Synge

Most of our knowledge of the glacial history of North-East Scotland is based on the researches of the two well-known geologists, T. F. Jamieson and A. Bremner. Nearly a hundred years have elapsed since Jamieson commenced his investigations in the Ellon area at a time when numerous exposures were laid bare during the construction of the railways to Peterhead and Cruden Bay.[1] In his last paper on North-East Scotland, published in 1906, he recognised three different tills, succeeding one another from below upwards in the following order : an indigo till containing shell fragments ; a grey till containing erratics from the west ; and finally a red till at the surface.[2] The latter is often interbedded with red silts, sands and gravels.

In his Ellon sequence, Jamieson recognised two glaciations. The earlier one, his First Glaciation, moved south-east carrying the indigo till from the bed of the Moray Firth, and east deriving grey till from the Banffshire Hills. His later or Second Glaciation travelled north, transporting material from the Old Red Sandstone rocks of Strathmore. Material laid down by this ice, consisting of red till, silt, gravel and sand, is known collectively as the Red Series. Such a northern movement of the ice suggested the presence of a barrier of Scandinavian Ice to the east on the bed of the North Sea. Jamieson also believed that this Strathmore Glacier advanced and retired at a time when the sea level was higher than at present, because of the presence of scattered fossils of seal, eider duck, starfish and arctic molluscs in certain of the fine silt deposits. An upper limit of about 300 feet O.D. for the Red Series in the Ellon area was correlated with a sea level at that height.[3]

North of Peterhead the Red Series were found to fade out in the vicinity of St Fergus, being replaced further along the coast by a Blue-Grey Series derived from rocks of that colour on the bed of the Moray Firth (*i.e.* Jurassic clays). This latter series, which extends along the southern shores of the Moray Firth as far west as the mouth of the Spey, is the uppermost glacial deposit in that area. The relationship between the Blue-Grey and the Red Series was noted by Jamieson

in a number of exposures between St Fergus and Buchan Ness. These showed that the two series are interbedded with one another, thus suggesting that they were deposited contemporaneously.[4]

Well outside the Ellon area, but closer to the uplands, Jamieson found evidence for a later expansion of the Highland Ice, after the withdrawal of the Strathmore and Moray Firth Ice had taken place. Morainic ridges observed overlying the denuded surface of the Red Series at Millden in the vicinity of Aberdeen were mapped as the terminal moraine of this Third Glaciation.[1] At first he believed that they marked the limits of a confluent Don-Dee Glacier,[1] but later attributed them to a Dee Glacier, whose snout had been deflected north by the abrupt edge of the 400-foot plateau that borders the south bank of the River Dee.[2] This glacier is believed to have swept away deposits of the Red Series that formerly occupied the low-lying ground at the mouths of the rivers Don and Dee. Red clay caught up by the advancing ice was sometimes seen embedded in the morainic gravels.

Bremner was the first to record evidence for an early glaciation from the north.[5] This is represented by the southward carriage of erratics in south-east Aberdeenshire, clearly shown by the distribution of boulders of Bin Hill gabbro and the dolerites of Barra Hill and Over Hill. With this same glaciation Bremner associated the few Norwegian erratics (rhomb-porphyry and laurvikite) that are sparsely scattered throughout East Aberdeenshire.[6] He suggested that the indigo drift of Jamieson could have been deposited by Scandinavian Ice from the north-east before the Highland Ice had become powerful enough to keep it off the coast.

Along the southern borders of the Moray Firth the lower drift contains erratics from the south. This was therefore correlated with the glaciation which deposited the Red Series, that is, the Second or Strathmore Glaciation. At that period the high sea level advocated by Jamieson could not have existed. This was proved by the presence of a series of dry overflow channels cut in rock at low altitudes within the limits of the Red Series. These channels are all sloping north parallel to the present coastline. Bremner showed that they were cut by drainage flowing north from lakes impounded by a waning Strathmore Glacier lying off the present coastline. The absence of such channels north of Stonehaven, between Muchalls and Findon and between Aberdeen and the Ythan estuary, was explained by the later advance of Highland Ice across the present coastline during the Third Glaciation. Such an advance of the ice from the west would tend to fill such channels with till, thus obliterating them from the landscape.

The extent of the Third Glaciation, as visualised by Bremner, appears to be greater than that advocated by Jamieson.[7] With it he includes the Blue-Grey Series of the Moray Coast, because it post-dates a drift from the south that he had already assigned to the Second Glaciation. Further south, between Aberdeen and Glen Esk, the terminal moraine of the Third Glaciation was mapped. Elsewhere the glacial limits must be regarded as approximate only (Fig. 1). A later Fourth or Valley Glaciation is indicated by large readvance

moraines at the Moor of Dinnet in the valley of the Dee,[8] and at Bellabeg in the valley of the Don.[9]

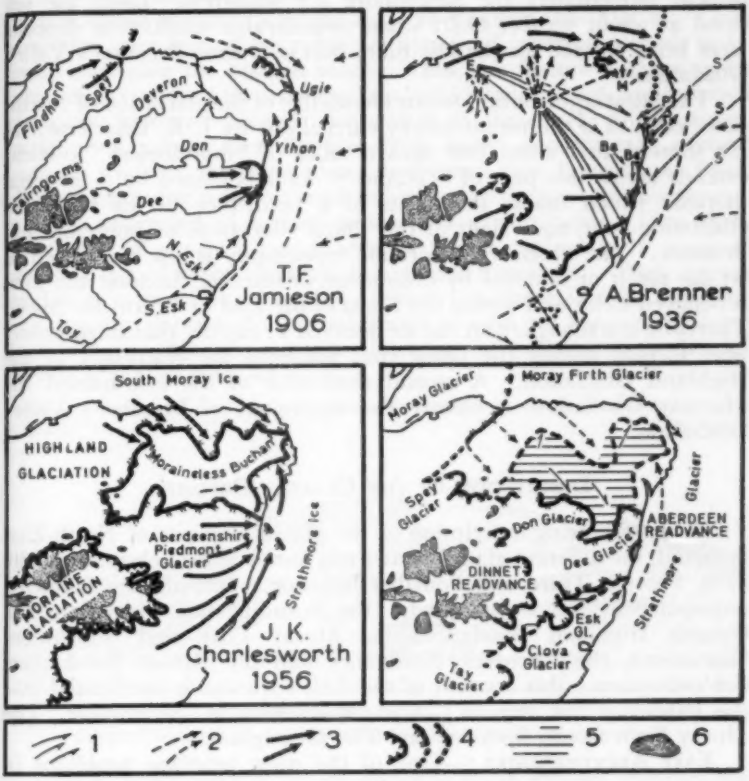

Fig. 1. The glacial sequence in North-East Scotland according to different investigators.

1. Direction of First Glaciation: 2. Direction of Second Glaciation: 3. Direction of Third Glaciation: 4. Glacial limits: 5. Areas unglaciated during Last Ice Age: 6. Highlands over 2,400 feet.

Abbreviations denoting different erratic trains: E—Elgin sandstone: N—Netherley diorite: Bi—Binn Hill gabbro: L—Longmanhill granite: M—Maud norite: P—Peterhead granite: Ba—Barra hill dolerite: Be—Belhelvie dolerite: S—Scandinavian erratics—Rhomb-porphyry and laurvikite.

Sources: T. F. Jamieson (Ref. 1, 2, 32): A. Bremner (Ref. 7): J. K. Charlesworth (Ref. 12): bottom right map author's interpretation.

Recently a detailed survey of certain temporary exposures behind the Bay of Nigg at Aberdeen was carried out by Scott Simpson. Here it was found that the Red Series lay in close juxtaposition to Jamieson's terminal moraine, but no section which showed the latter overlying the former was seen. The sequence observed could be explained on the basis that no glaciation affected the area after the Strathmore Glacier had receded.[10] Further research showed that an 80- to 100-foot sea

level associated with red laminated brickclays of the marine type and a lower limit of the marginal drainage channels at 100 feet O.D.[11] was present immediately the Strathmore Ice withdrew. Later the sea stood at about 30 feet O.D. when considerable solifluction deposits were being formed for the last time, that is, during Bremner's Valley Glaciation.

The latest contribution to our knowledge of the glaciation of North-east Scotland is the recent survey carried out by J. K. Charlesworth. He showed that some 800 square miles of 'moraineless' lowland extends across this part of Scotland.[12] It is bordered by a terminal moraine which marks the limits of a readvance of his Highland Glaciation—the equivalent of the Third Glaciation of Jamieson and Bremner. The absence of morainic topography is not considered to be the result of removal by erosion or weathering, because the area is believed to lie well within the limits of the Last or Würm Ice Sheet. Therefore it is thought that the ice decayed so rapidly that no moraines were formed during the phase that preceded the readvance of the Highland Glaciation. A second readvance of the ice, named the Moraine Glaciation, is clearly the equivalent of Bremner's Valley Glaciation.

Description of the Glacial Deposits

In the following description of the glacial deposits of North-East Scotland, the different glacial phases will not be named chronologically First, Second, Third and Fourth Glaciation. Instead, the following nomenclature will be adopted: the Scandinavian Glaciation, the Greater Highland Glaciation, the Moray Firth and Strathmore Glaciations, the Aberdeen Readvance and the Dinnet Readvance. For convenience this account of the drift sequence is subdivided into the following five regions: East Aberdeenshire, Strathmore, The Moray Firth Coast, Speyside and The Grampians.

East Aberdeenshire:—One of the most puzzling problems in this region is the origin and stratigraphical position of the Aberdeen moraines. An examination of the area some five miles north of Aberdeen, where a number of large gravel pits have been opened in recent years, has thrown some light on this problem. Here one striking feature, the esker-like Fife Hills ridge, extends north and south between the main road (A. 92) and the coast for a distance of two miles. It stands about fifty feet above the surrounding terrain, its crest reaching 150 feet O.D. Along its eastern margin a level terrace, composed of red, horizontally laminated brickclay containing marine shells in places, extends to the coast at about 75 feet O.D. This platform was regarded as a glacial marine sediment by Jamieson [13] and as a fluvio-glacial lake-sediment by Bremner; the latter believed that the shells in it were derived from till formed by glacier ice passing over marine muds.[14] According to Jamieson these clays underlie the sands and gravels which form the Fife Hills.[15] Scott Simpson showed that they might be marine sediments of a late-glacial 'hundred-foot' sea overlying the base of the Fife Hills.[11]

Recently two large transverse sections were exposed right across the Fife Hills ridge. These show that the feature is not a true esker but a line of confluent delta fans composed of bedded sand containing narrow bands of gravel and red clay, all dipping east (Fig. 2). Only along the west face of the ridge are contorted morainic gravels to be found overlying the bedded sands. Thus this feature appears to be very similar to the ' transverse eskers ' of Finland, which are terminal moraines deposited beneath the waters of the sea.[16] If this interpretation is correct, then the Fife Hills would appear to be derived from an ice front standing, along its western face, beneath sea level. The neighbouring ridges of sand and gravel to the west and south-west are also composed of bedded sands of a similar type. They show horizontal or gently dipping beds in places capped by a layer of unsorted gravel often showing disturbance structures. They appear similar to true eskers, acting as ' feeders ' to the Fife Hills moraine. The capping deposit of unsorted gravel or even till has already been described as ablation moraine, lowered on subglacial sands and gravels as the ice decayed.[17]

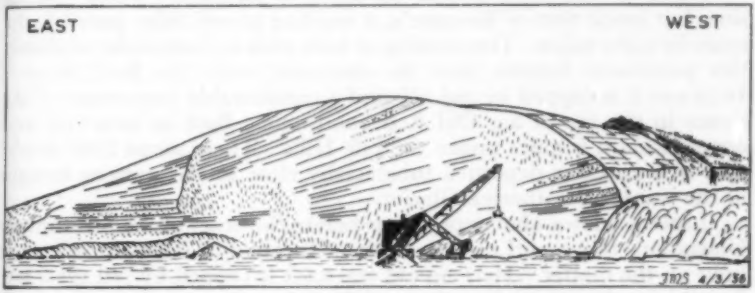

Fig. 2. Transverse section of the Fife Hills showing bedded sands (lines) and gravels (stipples) obscured in places by slumped material (vertical pecked lines).

Any interpretation of these deposits must explain the curious presence of bands of red clay.[18] Such bands are not very numerous or very thick. Irregular masses of this same clay are found in the overlying gravels as well. This must have originally been derived from Strathmore drift, but its presence does not necessarily imply the proximity of the Strathmore Glacier itself. Any later advance of local ice across territory vacated by the above glacier would incorporate large masses of red drift in its own ground moraine. This interpretation differs from that of Scott Simpson who regards the Fife Hills as a feature which was deposited between a local glacier from the west and the Strathmore Glacier from the south—the red clay being derived from the latter and the coarser material with western erratics from the former.

If a readvance of Deeside Ice did occur at Aberdeen, it should be possible to map its terminal moraine. A survey in the field carried out by the writer showed that this was indeed the case (Fig. 3). The limits of this readvance outline a large Dee Glacier and a lesser Don

Glacier. The map clearly shows that the former Dee Glacier swung north at its lower end in the neighbourhood of Dyce. This northward deflection of Deeside ice occurred only in the Aberdeen district ; no such deflection has been noted further south. In the coastal area north of Stonehaven the detailed survey carried out by Bremner showed that the Dee Ice there flowed somewhat south of east.[7] The case for a separate Aberdeen Readvance after the dissolution of the Strathmore Glacier would be strengthened if the marine brickclays of the ' hundred-foot ' sea could be seen lying between the Aberdeen morainic gravels and the Strathmore drift.

As the Dee Glacier retreated the sea level dropped rapidly from the hundred-foot level. By the time the glacier front had receded to Cults the sea level stood at 25 ft. O.D. at the most. This is shown by the Den Burn marginal spillway which is deeply trenched down to the 25-foot contour. Even at an earlier stage the sea level was low, as shown by the descent of the Foveran spillway to a similar level. Moraines marking halts during the retreat of the Dee Glacier occur at Culter and Durris.

North of Aberdeen, outside the limits of Jamieson's Third Glaciation, but inside that of Bremner's, a winding gravel ridge parallels the coast for eight miles. Terminating at both ends in hummocky moraine, this prominent feature must be associated with the Red Series.[19] In places it is capped by red till, and a considerable proportion of the stones in the gravel are Old Red Sandstone. Both in structure and composition it is quite unlike the Fife Hills. There seems little doubt that it is an esker deposited subglacially close to the western margin of the waning Strathmore Glacier.

Little is known about conditions before the onset of the Strathmore Glaciation, but a cliff section south of the Bay of Nigg throws some light on the matter. Here an old sea-stack is capped by red till a few feet thick. It is joined to the mainland by a narrow ' plug ' of this same till known as the Bridge of One Hair. This ' plug ' is about a hundred feet thick, and fills a rock-cut chasm whose floor stands a few feet above present sea level. Therefore the stack must have been cut at a time when the sea level stood for a considerable period slightly above its present level, before the deposition of the red till. The relationship between this phase of marine erosion and the older drifts is not known.

STRATHMORE :—Throughout the whole of Strathmore the last ice to cover the region came from the south-west. In places it overlies till deposited by ice moving south-east from the Grampians. The limits of the Strathmore Glacier are to be found in the hilly terrain north of the Highland Boundary Fault. But wherever large valleys open out on to the lowlands the limits of the red till of that glacier extend upstream for a considerable distance. Such invasions of the mountain glens by lowland ice became progressively more intense from north-east to south-west. Thus in Glen Bervie the red till has been carried one mile north of the Highland Boundary Fault, whereas in Glen Clova a distance of four miles has been recorded.[20] This implies a north-easterly flow of Strathmore Ice at a time when the

Fig. 3. The Glacial morphology of North-East Scotland (based on numerous maps and publications by
Based upon the Ordnance Survey Map with the sanction of the Controller of H

and publications by A. Bremner and on the author's field observations).
of the Controller of H.M. Stationery Office.

local Grampian glaciers were weak. Judging by the great profusion of dead-ice features which extend along the base of the Grampians and occur up to the thousand-foot contour, the Strathmore ice appears to have become stagnant during its decay.

There is no evidence to show that Strathmore was affected to any great extent by the later advance of Grampian ice. The eastern limit of the Tay Glacier during the Perth Readvance stage has yet to be mapped.[21] The evidence does, however, suggest that such a later readvance of ice in Strathmore cannot have extended as far east as the basin of the South Esk because the bulk of the outwash in this valley is associated both with moraines in Glen Clova and a ' hundred-foot ' sea level.[22] Such a high sea level is associated with the Perth Readvance, but did not recur here at any subsequent period.[21] It is possible that the large moraine observed crossing Strathmore six miles west of Forfar marks the limit of this readvance. Further west such moraines are absent.[23] It is probable that the maximum of the valley glaciers in Glen Clova and Glen Esk occurred at this time.

Striking evidence for an expansion of the Dee Glacier subsequent to the decay of the Strathmore Glacier was observed in the Glensaugh area. Here, two miles east of the summit of the Banchory-Edzell road (B. 974) the watershed between Glen Dye and the Howe of the Mearns is breached by a gorge 300 feet deep, cut in gneiss (Fig. 4). The intake at about 1,170 feet O.D. is located one mile to the north of the natural watershed, a fact which implies considerable fluvial erosion, possibly during more than one glaciation. Continuing south this spillway cuts straight through thick fluvioglacial gravels and associated drainage channels of the Strathmore marginal kame belt. It debouches on to the lowland in a fan of gneissic gravel. This shows that the channel last operated when the Dee Glacier was large enough to impound a lake in Glen Dye after the Strathmore Glacier had disappeared from the Howe of the Mearns.

The association of different sea levels with the various glacial phases is clear in this region. The so-called ' hundred-foot ' beach attained its full development before the Perth Readvance had taken place. Laminated brickclays in the Montrose Basin contain a marine fauna which fades out in the uppermost beds.[24] These are overlain by outwash gravels laid down when the sea level was still high. The highest raised beach, so well-developed between Inverbervie and Montrose, lies slightly above the hundred-foot contour.[25]

The subsequent fall of sea level continued to well below that of the present. In the Montrose Basin this period is represented by the Boreal forest peat which underlies the fertile Carse clays, deposited when the sea level again rose to about 20 feet O.D.[26] in the post-glacial Atlantic period.

The Moray Firth Coast :—The sequence of glacial deposits generally recognised in North Banffshire was worked out by H. H. Read in 1923.[27] Drift from the west and north-west, including shelly drift and erratics of Jurassic clay both blue-grey in colour, was assigned to the First Glaciation. This is overlain by a series of sands, clays and gravels named the Coastal Deposits. These are believed to have been

deposited in ice-dammed waters before the onset of a glaciation from the south. As this latter Second Glaciation retreated south an uppermost deposit of Late-Glacial sands and gravels was laid down. Later work by Bremner showed that this upper series must be associated with a glaciation from the north-west, rather than from the south.[28] It must be remembered that Jamieson, many years before, recognised that the last glaciation here was from the north-west, although he also included with it the blue-grey drift mentioned above. He suggested that it had a free southern edge.[29] This was confirmed by the writer who mapped a generalised limit of fresh drift-topography shown in Figure 3.[30] Such evidence shows that a re-assessment of the above sequence is required.

It is difficult to believe that this last or Moray Firth glaciation from the north-west could have crossed the coast of North Banffshire without depositing a boulder clay. Therefore it is suggested that the drift assigned above to the First Glaciation is really that of the last glaciation. In most sections this drift is never capped by a later boulder clay but only by the clays, sands and gravels of the Coastal Deposits. Also none of the recorded sites of Jurassic and shelly drift lie outside the limits of this glaciation. In certain coastal sections the Coastal Deposits are capped by a boulder clay containing erratics from the south and from the west. For this reason the glaciation from south to north has been placed after the one from the north-west by Read.

It is possible to interpret these sections in another way ; namely, that the upper boulder clay may not be *in situ*. All these sections occur in localities backed by high ground, that is, in places where solifluction could readily operate, carrying boulder clay downslope on top of the Coastal Deposits below. If this boulder clay does in fact pre-date the gravels, then it would be assigned to the glaciation from the north-west, the erratics from the south being derived from an earlier drift. This would place the Coastal Deposits in the same position as the Late-Glacial gravels, which are never recorded in coastal sections. This conclusion is strengthened by the fact that these two deposits are never seen in the same section. In this interpretation, therefore, the drifts of North Banffshire are all placed in a single glaciation, namely, the last or Moray Firth Glaciation.

On the higher ground between Huntly and the coast, not overrun by the Moray Firth Glaciation, the last ice came from the south, as seen by the great profusion of Bin Hill erratics. The evidence suggests that this northerly movement is contemporaneous with a movement to the south around Huntly itself. In the latter district the dominant carry of erratics is southwards. The only sign of a northward movement is represented by a few isolated boulders of gabbro from the Insch Mass, which must be assigned to a still earlier glaciation.

The general glacial sequence is revealed by an extensive exposure 200 feet high on the right bank of the river Spey opposite Rothes. Here three different tills have been recorded. At the base of the section there is a very compact red till, containing Old Red Sandstone and other erratics from the north-west. It is overlain by a thin layer of grey till from the south. Then follow fluvioglacial lake deposits

capped by a red till derived from the north-west, which differs from the lower red till in that it is less compact and contains no Jurassic erratics. On top of this there are fifty feet of fine fluvioglacial lake

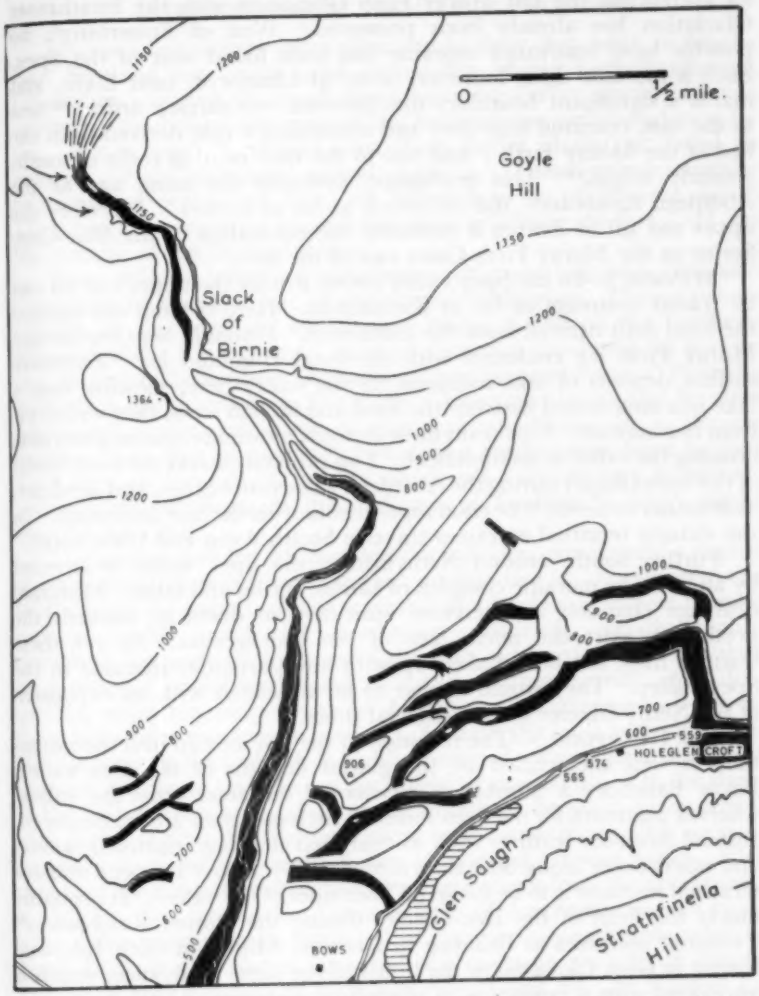

Fig. 4. Glacial spillways in the Glen Saugh area, Kincardineshire. Black areas indicate ill-drained floors of both marginal and overflow channels : arrows—small marginal spillways.

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sediment capped by a delta-fan spreading out from a small tributary valley. These upper lake deposits were laid down in waters impounded in the Spey valley as the last ice to cover the area receded northwards. Each of these three tills were correlated by Bremner with the three

glaciations recognised in East Aberdeenshire.[31] But if the Third Glaciation (Aberdeen Readvance stage) never extended over this area such a correlation will have to be revised. Jamieson's evidence for correlating the last Moray Firth Glaciation with the Strathmore Glaciation has already been presented. West of Fraserburgh no possible later readvance moraine has been found east of the Spey. Such a moraine does, however, occur at Lhanbryd, near Elgin, and marks a significant boundary line between two surface drifts ;[32] one to the east, coloured blue-grey and containing shells, derived from the bed of the Moray Firth ; and one to the west bearing rocks of south-westerly origin.[33] This readvance, probably the same age as the Aberdeen Readvance, did not reach as far as Rothes. Therefore the upper red till at Rothes is probably the equivalent of the Blue-Grey Series on the Moray Firth Coast east of the Spey.

Speyside :—In the Spey valley above Rothes the upper red till can be traced upstream as far as Knockando. Here it fades out against the local drift derived from the south-west. Probably here the foreign Moray Firth ice coalesced with the local Highland ice. Extensive surface deposits of lake sediment fill the valley here, showing that a lake was impounded between the local and foreign ice as they withdrew from one another. Upstream these deposits terminate against a moraine crossing the valley at Ballindalloch. This probably marks the outer limits of the Spey Glacier during the Aberdeen Readvance Stage, and need not, as Bremner believed,[34] be contemporaneous with the lake sediments. In the vicinity terminal moraines traverse Strath Avon and Glen Livet.

Further south, around Nethybridge, the Spey valley is covered by an ablation moraine complex of kames, kettles and lakes. Marginal drainage channels and terraces indicative of drainage towards the north-east, skirt the north face of the Cairngorms. As yet these features have not been linked up with any particular moraine in the Spey valley. They would appear to be associated with an expansion of the Nethy Glacier in Late-Glacial times.[35]

The Grampians :—The recession of the last ice cap into the mountains is well exemplified by the glacial deposits of the Dee valley. Below Banchory a number of recessional moraines cross the valley, whereas upstream for over ten miles no such moraines are encountered. Instead dead-ice features such as marginal drainage channels, kames and eskers occur along both sides of the valley. Above Dinnet a massive terminal moraine is to be found on both sides of the valley. It probably marks the limit of the Dee Glacier during the Dinnet Readvance.[36] Terminal moraines at Bellabeg in Donside, Migvie in Glen Esk, and Rottal in Glen Clova mark the limits of the same readvance, which is associated with a landscape of glacially overdeepened valleys.

In Deeside no further terminal moraines are found upstream from Ballater until the high valleys and corries of the Cairngorms are reached. Instead a very well-developed dead-ice topography is continuous along both banks of the Dee. In the Cairngorms periglacial phenomena[37] of extreme freshness were observed. These include mudflow levees observed on the slopes of Glen Derry and Glen Dee and stone pavements and stone polygons on the plateau summit

of Braeriach at 3,900 feet O.D. It is not known whether these were formed in Late- or Post-Glacial times.

Interpretation of the Glacial Sequence

Evidence has already been presented to show that much of North-East Scotland was unglaciated during the Moray Firth-Strathmore Glaciation. During the much more extensive earlier glaciations it is extremely doubtful if any part of the lowlands escaped inundation by ice. But in part of Buchan even these earlier glaciations failed to remove certain preglacial gravel deposits. These gravels, largely composed of pebbles of flint, are believed to be of Pliocene age.[38] They mark a preglacial marine shoreline at about 400 feet O.D. on the summit of the Buchan ridge.

Tors, isolated bosses of rock twenty or more feet high, are also thought to be characteristic of unglaciated landscapes. They occur on hilltops on the edge of ' Moraineless Buchan ' and on the northern summits of the Cairngorms. Most of them are developed on granite (*e.g.* those on Clachnaben, Bennachie, Ben Avon and Beinn a' Bhuird), and others on schist (*e.g.* on The Buck). These may be residual features developed under conditions of chemical weathering in a climate warmer than that of to-day.[39] Therefore they cannot have formed since the Last Interglacial, part of which was warm enough to support a hippopotamus fauna in the midlands of England.[40] They might even be older still.

The surface drift in ' Moraineless Buchan ' has experienced a degree of weathering more intense than that surrounding it. Everywhere the hills exhibit the smooth contours typical of a landscape subject to mass wasting under periglacial conditions. Bedrock, usually highly shattered, outcrops on the tops of the hills, whose slopes are covered by a mixture of shattered local rock and weathered drift. At Tillycorthie, some ten miles north of Aberdeen, the structure of one of these hill slopes was seen in section. Beneath the level summit of the hill the local gneiss bedrock is highly shattered. Festoons of shattered bedrock are drawn up between pockets of weathered till. On the slope of the hill pockets and layers of the shattered bedrock, interspersed with lenses of drift, fill the depressions in the underlying rock surface. At the foot of the hill over ten feet of oxidised till was found. The nature of the erratics present indicates a movement from the north-west.

Within the ' moraineless ' area no fresh till has been observed overlying either mechanically shattered or chemically weathered bedrock. Near Pitcaple the parent igneous rock contains pockets of deeply weathered rock overlain by completely weathered till. At Kintore an old quarry exposes over six feet of granite bedrock rotted by weathering. Similar disintegrated granite occurs on the west of Aberdeen city. In this case the decayed rock is overlain by Deeside till containing fresh granite.[41]

There is reason, therefore, to believe that ' Moraineless Buchan ' has not been covered by glacier ice since a period warmer than the present day. This would be consistent with the view that the chemical

weathering observed occurred during the Last Interglacial and was succeeded by periglacial conditions contemporaneous with the Last Ice Age represented by the Moray Firth-Strathmore Glaciation.

If this interpretation is correct denuded kettle-holes in the ' moraine-less ' area should contain lake sediments of the Last Interglacial sealed beneath solifluction gravels of the Last or Würm Ice Age. Such undrained hollows do occur in certain areas (*e.g.* at Whiterashes). No convincing interglacial deposits have yet been recorded although Bremner noted two localities near Foveran where peat was caught up in red Strathmore till.[42] Another possible interglacial peat was reported from the Burn of Benholm, near Inverbervie, underlying Strathmore till.[43]

The glacial sequence may be described as follows (Fig. 5) : The oldest or SCANDINAVIAN GLACIATION invaded East Aberdeenshire from the east or north-east. Then followed an expansion of Scottish ice during the GREATER HIGHLAND GLACIATION. Pressure of Scandinavian ice standing off the coast caused the outflowing Scottish ice to split into a north and south moving stream in the Buchan area. At the point of bifurcation of these two streams the Pliocene gravels are situated, just where glacial erosion would be at a minimum. This glaciation is most likely the equivalent of the Alpine Riss Glaciation. It was followed by an interglacial period during part of which chemical weathering was active. During the Last or Würm Glaciation, one stream of Scottish ice fanned out from the Firths of Tay and Forth. Part of this ice—the STRATHMORE GLACIER—was forced north along the coast owing to pressure from the east from the great glacier discharging from the Scandinavian Ice Sheet.[44] At the same time ice from the west crossed the Moray Firth from the Northern Highlands—the MORAY FIRTH GLACIER. The Dee Glacier had not yet attained its maximum extent ; its limits are not known during this phase.

As the Strathmore Glacier wasted away a period of high sea level (*c.* 100 feet O.D.) reigned. Red clay, derived from the red till and glacial lake clays by fluvial and marine erosion, were deposited in estuaries. These deposits, the laminated brickclays, are never found above about 60 feet O.D. With a return of colder conditions glaciers advanced from the Grampian ice cap. Only the larger glaciers reached the sea (*i.e.* the Moray, Dee and Tay Glaciers). During this same readvance—the ABERDEEN or PERTH READVANCE—copious outwash from the Esk and Clova Glaciers deposited the gravels of the ' hundred-foot ' beach in the late-glacial sea. As these glaciers started to recede the sea level dropped to about 80 feet O.D. and eroded the front of the Aberdeen moraine. With the further decay of the glaciers the sea level dropped to 25 feet O.D., or even lower. By the time the snout of the Dee Glacier had receded to Banchory extreme arctic conditions may have disappeared for good. This is suggested by the distribution of frost wedges, which have not been observed above Durris. Such structures only form to-day in arctic localities with a mean annual temperature between $-5°$ C and $-12°$ C, and a continental climate.[45]

The milder conditions which followed led to the general decay of this glacier. There followed another cold phase, marked by a

readvance of the Dee Glacier. This DINNET READVANCE corresponds to the last phase of severe solifluction and a 30-foot sea level at Aberdeen.[46] Further evidence of such a sea level associated with cold conditions is found beside the Ythan estuary. Here fossil stone polygons are developed on the surface of a gravel terrace at that height. Such structures occur to-day on delta flats in the tundra and sub-arctic areas of the world in relatively humid climates with a mean annual temperature between 0° C and 5° C.[47] This cold phase is generally correlated with the Loch Lomond readvance.[48]

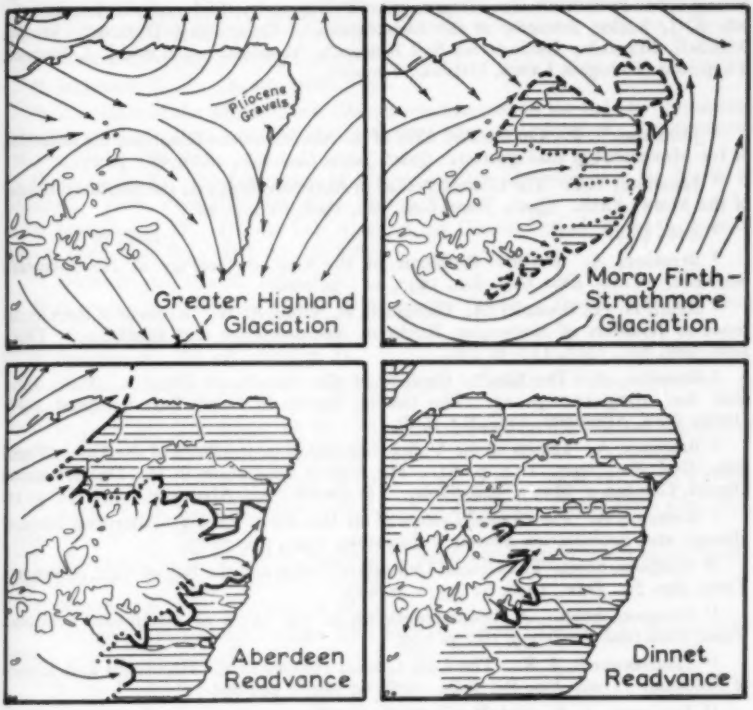

Fig. 5. The glacial sequence in North-East Scotland.

With the final decay of the valley glaciers, a fall in sea level to well below the present level heralded the beginning of the Post-Glacial period. Great spreads of pine forest, and Man himself, arrived in Scotland during this Boreal phase. During the following Atlantic phase the sea level rose to about twenty feet above its present level and cut a well-marked beach in unconsolidated deposits such as till, gravel or clay. This marine transgression, termed the Post-Glacial, Littorina or Flandrian, was associated with the Carse Clays of the Montrose Basin. The clays contain shells of *Scrobicularia*, a mollusc now extinct from these shores.

In Scandinavia a cool period ended the Atlantic phase. This climatic deterioration was sufficiently intense to cause an expansion of the glaciers in the high mountains.[19] It is possible that some of the fresh periglacial phenomena observed in the Cairngorms were formed at that time.

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THE U.S.S.R.: A RE-APPRAISAL OF MACKINDER'S HEARTLAND CONCEPT

DENNIS R. MILLS

Based on a lecture given on 1st March 1956 to the Lincoln Branch of the Geographical Association

THE conflicts between continental powers and maritime powers are a well-known historical theme. The migrations of nomadic peoples outwards from Central Asia are likewise an important feature of world history. Upon these two historical truths rests Mackinder's geopolitical concept of the supremacy of the Heartland. The Heartland is both the centre of the world's biggest land mass and the centre from which these migrations stemmed.

Mackinder's thoughts on the Heartland area were first made public in 1904 to the Royal Geographical Society. On this occasion he used the term " pivot area ", which he defined as the regions of Arctic and continental drainage in Eurasia—that is to say, that area of land inaccessible to the maritime nations. In addition to this area he distinguished three other major geopolitical regions of the world (Fig. 1).

1a. Around the edge of the pivot area was the INNER or MARGINAL CRESCENT, including the remainder of Eurasia and North Africa, except Britain and Japan.

1b. The GREAT DESERT of the Sahara and Arabia.

2. The OUTER or INSULAR CRESCENT, including the Americas, Australasia, Japan and Britain.

Mackinder had this system of regions in mind when he said : " I ask for an inner mobility, for a margin densely populated, and for external sea forces." [1] The significance of these three elements becomes more obvious from a study of the Heartland concept—as the idea of the pivot area came to be called in Mackinder's book *Democratic Ideals and Reality*, first published in 1919. The Heartland included the Arctic and continental drainage basins of the pivot area, and also the high tablelands of central and east central Asia (Tibet, Inner China). Two other features of its physical geography are important : first, the continental climate which maintains only a steppe or desert vegetation in a broad almost continuous sweep from Hungary to Manchuria ; second, the even broader sweep of lowland territory beginning in Europe and extending as far east as the eastern bank of the Yenisey (for the Urals present no real barrier to movement, and in any case do not run the full width of the lowland plains).

Configuration and vegetation help therefore to account for the " inner mobility " and the great importance of the relatively small numbers of horse-riding nomads. The contrast lay with the densely peopled lands of Monsoon Asia, Europe, and parts of the Middle East, *i.e.* the " margin densely populated ". Situated in, or having access to this margin were the " sea forces ".

But the sea forces could not penetrate the Heartland. Indeed

Mackinder extended his boundaries to delimit a strategic Heartland—"the region to which, under modern conditions, sea power can be refused access".[2] The extensions were narrow in the east, non-existent in the south, but broad in the west. Here they included the basins of the Baltic and Black Seas, and the plateau lands of Asia Minor and Persia.

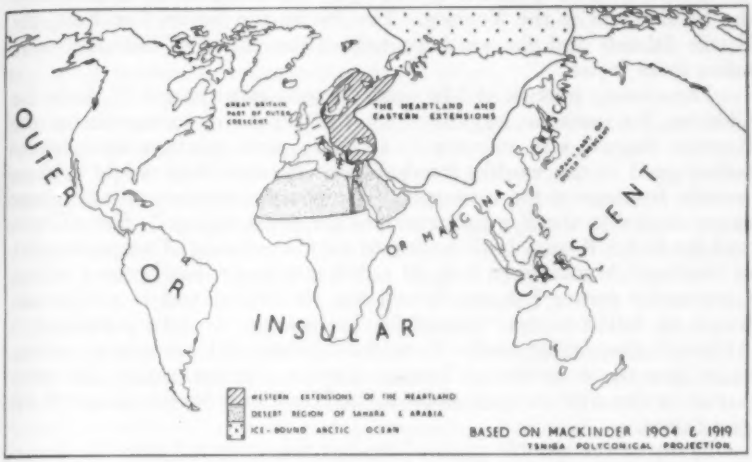

Fig. 1. Geopolitical Regions of the World.

The weakness in the Heartland's armour can now be perceived. Protected on the north by Arctic ice, and to the east and south by high mountain ranges and tablelands, it lay unprotected on the western flank, in Eastern Europe where the European plains are contiguous with the Asiatic. Hence Mackinder's long-famous dictum :

> "Who rules East Europe commands the Heartland.
> Who rules the Heartland commands the World-Island.
> Who rules the World-Island commands the World." [3]

In 1904 Russia had already commanded much of the 'smaller' Heartland and its approaches through Eastern Europe for over a century, from the time when Catherine established Russian power in the Crimea. It should be realised, too, that the main trend of world events since 1904 seems to have led to a strengthening of the pivot or Heartland state.

For instance, in the First World War, Germany, owing to her commitments in other theatres of war, failed to follow up her military victories over Russia and the Bolshevik revolution of 1917 eventually set in train a whole series of economic and political measures which have increased enormously the industrial and military power of the Soviet Union. The pivot state became the only Communist country in a capitalist world.[4]

As a result of the Second World War, the Soviet Union extended

the whole of its western frontier further westwards (Karelo-Finnish S.S.R. ; Estonian, Latvian and Lithuanian S.S.R.'s ; the Kaliningrad Oblast (East Prussia), East Poland, Ruthenia and the Moldavian S.S.R.). In most cases this represents the reoccupation of land held by Tsarist Russia ; but East Prussia is an entirely new accession of territory. In South Central Siberia she acquired the formerly Chinese-dependent state of Tannu-Tuva in 1944, thereby gaining control over the headwaters of the Yenisey. Finally, in the Soviet Far East, the Kurile Islands and the southern half of the island of Sakhalin were taken from Japan.

The closing remark of Mackinder's 1904 paper was : " Were the Chinese, for instance, organised by the Japanese, to overthrow the Russian Empire and conquer its territory, they might constitute the yellow-peril to the world's freedom, just because they would add an oceanic frontage to the resources of the great continent, an advantage as yet denied to the Russian tenant of the pivot region." Since China and the U.S.S.R. now both belong to the Communist ' Commonwealth of Nations ' Mackinder's fear, in a different sense, has become a fact. Communist power has overflowed the Heartland and is now established in buffer states situated in " a margin densely populated ". Although disquieting to the West, the advance of Communist government into the countries of Eastern Europe represents only the occupation of the western extensions of the Heartland by the power of the pivot state.

Many of the trouble spots of the last ten years fall into the framework envisaged by Mackinder. The Korean War can be interpreted as an attempt to thrust the maritime powers from the World-Island. There seems to be a lull at the moment in the strife in Indo-China and Malaya—is this because, being relatively distant from the Heartland, they are to be left without support from it, until a later stage ? The southern flank of the Heartland, now sheltered by a servile Tibet is presumably considered secure from attacks by land forces. Nevertheless the recent visit of Bulganin and Khruschev to India, Pakistan and Burma may indicate that a line of expansion is being prepared there (or perhaps the need for a counterbalance to China has been felt). The return of the Porkkala naval base to the Finns may look like a retreat on the part of the Soviet Union, or is this a case of *reculer pour mieux sauter* ?

The weakest part of the strategical armour surrounding the Heartland is clearly the Middle East. From the coast of northern Turkey to the centre of the Donbas Industrial Region is only 500 miles. It is not surprising that recent Soviet political manœuvres have been concentrated on the Middle East. Quite apart from the resources of petroleum, the region is also strategically important for the maritime powers because it forms a link between two of the most densely peopled but politically fragmented areas of the world—Western Europe and Monsoon Asia. Jerusalem was once regarded as the centre of the world; to-day it is at any rate at the cross-roads of the World-Island, between Africa and the pivot area, between Europe and the East.

In general it may seem that the second line of Mackinder's dictum

is gradually coming true : " Who rules the Heartland commands the World-Island ". Indeed Mackinder reasserted in 1943 the importance of his geopolitical concept in these words—" The Heartland is the greatest natural fortress on earth. For the first time in history it is manned by a garrison sufficient both in number and quality." But this was before the use of the atom bomb and jet aircraft.

However there are other considerations which must be borne in mind in attempting a modern evaluation of Mackinder's concept. These can be divided into the military or strategic on the one hand, and the economic or commercial on the other.

Amongst the strategic factors, the importance of air power was pointed out even in 1904 by Mr Amery, who saw in it something likely to diminish the significance of the conflict between land and sea powers.[5] The world has now almost reached the ultimate stage in the development of air attack when jet aircraft or guided missiles loaded with nuclear weapons will be able to reach any part of the Heartland.

Mackinder believed that the Heartland was secure on the north, but successful Arctic navigation has been a reality for twenty years. This may be due partly to a retreat of the southerly limit of pack ice during the last fifty years, but it is certainly a result of Soviet maritime activity in the region which has followed the establishment in 1919 of the Arctic Institute in Leningrad and in 1932 of the Glavsevmorput, (the Chief Directorate of the Northern Sea Route). The motives are obviously partly economic, partly strategic. Although, according to Baranskiy (*Ekonomicheskaya Geografiya*, 1954), Igarka on the lower Yenisey is the fourth saw-milling centre of the Union, there can hardly be sufficient economic activity in the Far North to warrant the vast expenditure on installations known to be there. According to Mason, seventy-two permanent or semi-permanent polar stations had already been established in 1935 for the purpose of weather and ice-forecasting.[6] These were all equipped with radio stations, and it is not unreasonable to suppose that they have formed a basis for the establishment of a radar warning system similar to that which stretches across Alaska and Canada.

Although the Russians have been able to develop a sea route capable of linking European U.S.S.R. with the Soviet Far East in comparative shelter, it is interesting to note that the Germans were able to establish and maintain throughout 1943 a U-boat base at the northern tip of Novaya Zemlya (although it is not clear whether there were actually any shore installations). Apparently the only ill effects were inaccurate torpedoes and a few bent periscopes.[7] This illustrates the difficulties of defending such a vast shoreline both from sea and air attack. The Soviet Arctic shore stretches through 160° of longitude, whereas the North American shore is only 120° long ; in any trans-polar conflict the Soviet Union therefore has a longer coastline to defend, since the shores lie in approximately similar latitudes.

Clearly then, the physical security of the Heartland no longer exists. Indeed there is much in Soviet literature to suggest that the Russians feel that the fortress has become a trap. They have produced maps showing an almost complete ring of air air bases around the Soviet

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Union and the perhaps obvious conclusion has been drawn. Recently it has been pointed out that a combined air, sea and land force operating in the Dardanelles could bottle up and render ineffective the Russian Black Sea Fleet.

One natural safeguard against the effects of any kind of attack on the Heartland is the dispersal of heavy industrial centres. To a certain extent this has been carried out by the five-year plans. Before 1930 the Ukraine was the only steel-producing region of consequence. The second five-year plan, beginning in 1933 saw the establishment of the Ural industrial region. During the third five-year plan the industrial developments in the Kuznets Basin and the Soviet Far East were begun.[8] Yet industrial dispersal has probably not gone so far as one would suppose. This table of iron and steel production indicates a still marked concentration in the Donbas and the Urals.

	Pig iron	Steel
Ukraine and Crimea . . .	52	40
Urals	33	35
Rest	15	25

Estimates of iron and steel production in 1950 as percentage of national output (Shimkin[9]).

However, the share of the Ukraine and the Crimea continues to fall slowly : in 1955 it amounted to 48·5 per cent of the pig iron and 38·7 per cent of the steel output.[10]

To sum up, this consideration of the two strategic factors—distance and dispersal—shows the Soviet Union to be less well-placed, on balance, than fifty or even ten years ago. However, there is much evidence supporting the view that the Russians believe that the conflict between the Communist and capitalist systems may come to be decided mainly in terms of economic and commercial competition : for instance the recent Soviet announcement of demobilisation, and Marshal Bulganin's speech on the 15th of July 1955 which included the phrase, " Let everyone prove in peaceful economic competition that he is right ". In this case a wholly different set of criteria have to be examined.

The economic importance of the Soviet social and political system is difficult to estimate, but cannot be ignored. Since they are able to manipulate the direction of industrial effort, Communist governments may be able to outstrip the West in providing economic and technical assistance to countries such as India and Burma, and military and economic assistance to the Arab countries. Professor Erhard pointed out in February 1956 that " The Russians starve their own consumers to export on Government account for political objectives ". Soviet economic and technical aid activities have been going on in different parts of the world since Stalin's death, and are now gathering pace.

The sixth five-year plan, announced in January 1956, outlines a 70 per cent increase in heavy industrial production and only a 60 per cent increase in the production of consumer goods. The latter figure hides some very substantial improvements, the most spectacular being

a planned increase of 508 per cent in the production of washing machines, to a level of 528,000 a year.[11] But they do not represent the rate of increase in the production of consumer goods appealed for by Malenkov in 1953 and partially achieved in 1954 and 1955. Some of the vast production of heavy industrial goods is presumably intended for export along with the technicians being trained in such large numbers.

In the long term, however, the natural resources of the Heartland may decide the issue. A complete survey is impossible here, so that attention will only be focussed on a few of the resources critical to the development of the Soviet economy.

1. Supplies of Fuel and Power.—Although the U.S.S.R. is suffering from a shortage of coal at the moment, coal supplies may not eventually be decisive in limiting Soviet industrial progress, for several reasons. The Soviet Union is clearly well on the way to producing atomic energy in large quantities, for the current plan envisages the construction of atomic-energy stations with a total capacity of 2-2·5 million kW. The production of hydro-electric power, although limited by aridity, frost and the difficulty of finding dam sites, is going up rapidly. In 1956-60 the capacity of hydro-electric power stations is to increase by 2·7 times, so that by 1960 the production is expected to be 59,000 million kWh. ; (cf. the *total* production by authorised undertakings in this country in 1955 was 73,000 million kWh.).

The shortage of suitably located coking coals has for twenty years or more been a serious handicap to the Soviet steel industry. The use of lignitic and sub-bituminous coals could cheapen the production of steel enormously. In Australia the successful production of metallurgical coke at commercially competitive costs from the brown coal of Yallourn, Victoria, has recently been announced and a similar development in the Soviet Union could have considerable effects on steel production.[12] Geologists have produced widely varying estimates as to the reserves of petroleum in the Soviet Union, so that speculation seems fruitless. On the other hand, Soviet oil production has increased more than threefold since the end of the war, and the sixth five-year plan envisages a further increase of 91 per cent.

2. Supplies of Metal Ores and Other Minerals.—Whereas atomic energy represents a means of circumventing the shortage of coal for fuel, there seems little prospect of a similar technological advance in the smelting of metal ores. Nevertheless improvements in the methods of concentrating and purifying ores will mean a great deal to the Soviet Union, for many of her reserves consist of low-grade or chemically difficult ores, often located at a considerable distance from present suitable coal supplies. The concensus of opinion in the West suggests that, although the output of tin, aluminium and some ferro-alloys is lagging behind requirements, the U.S.S.R. is unlikely to be seriously hindered by a shortage of any important mineral in the foreseeable future, even if the present rate of development continues unchecked.

3. Agriculture.—The amount of good agricultural land in the Soviet Union has often been overestimated. Moreover, despite the

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improvements in agricultural methods and the extension of cropland, the U.S.S.R. has done little more in the last thirty-five years than to keep pace with the food requirements of her growing population. Domestic wool and natural rubber have also been in short supply. Whereas in 1940-54 industry doubled its output, agriculture achieved only a 10 per cent increase.[13] This is a serious situation if the Soviet Union intends to maintain self-sufficiency in food supplies. Indeed it is possible to detect a crisis in food production at the moment for the Soviet-Canadian trade pact provides for the sale of at least 1·5 million tons of wheat to the Soviet Union in the three years 1956-58. Extensions of cultivated land in Siberia, western and northern Kazakhstan are hemmed in by a short growing season to the north ; and to the south, by aridity, lack of water for irrigation, and excessive solonisation of the soils. The programme which was initiated in the spring of 1954 aimed at increasing the area of grain production by 64 million acres [14] and the area of all cropland by 74 million acres.[15] This area was to be principally in Kazakhstan and the southern parts of western Siberia, and since the total cropland in the Soviet Union in 1953 was estimated at 388 million acres,[14] the new areas represented an increase of about one-sixth.

Apparently things have not gone very well for the plan. Mr Khruschev, an eager advocate of the scheme, is reported as having said that " When the new state farms were established, some of them were set up in a hurry and not quite successfully. Land was chosen unsuitably, not only because of the (inadequate) amount of rainfall, but also because of the (excessive) salt content of the soil. . . . There is little rain in Kazakhstan." [15] A virtual admission of failure, but a failure that might be redeemed.

The intensification of agricultural production has been carried out in the older lands of European Russia, and the speeding up of this process has no doubt been considered as a way out of the agricultural crisis. But in this sphere the process of socialisation has met with least success, for it could not make virtually the clean start that was possible in industry and the new lands.

4. Distance. Distance in fact must be considered the worst enemy of Soviet agriculture and industry—the very feature of the Heartland which made Mackinder believe in the strength of the pivot state. The industrial areas of the Union are still interdependent in many ways, and yet they are strung out over vast distances. It is 2,000 miles from Moscow to the Kuznets Basin, yet that is less than half-way to Vladivostok.

Chauncy Harris estimates that Soviet railways carried 85 per cent of Soviet freight traffic in 1951, and that the railways used 30-40 per cent of the Union's coal production. This compares with about 12 per cent in the United Kingdom, and 20-25 per cent in the U.S.A.[16] The efficiency of the transport system will be considerably increased in the next few years. The current plan provides for the introduction of electric and diesel locomotives in such large numbers that by 1960 they should be hauling 40-45 per cent of all railway freight ; 6,500 kms. of new line are to be laid down. Canal traffic in recent years has only

been about 8-10 per cent of total freight traffic, but the vast amount of canal construction carried out in the last twenty years in European U.S.S.R. will soon make a bigger contribution to the national economy. It is planned that in 1956-60 the amount of river and canal freight will increase by 80 per cent, whereas railway freight is expected to increase by only 42 per cent.

The biggest improvements and innovations in canal transport are being brought about in central and southern European U.S.S.R. Yet great stress is being laid upon the development of heavy industry in Siberia and the Asian Republics. For instance, at Sokolovka in northern Kazakhstan a new iron-ore centre is to be opened up, and by 1960 should be producing 5,600,000 tons per annum of concen-

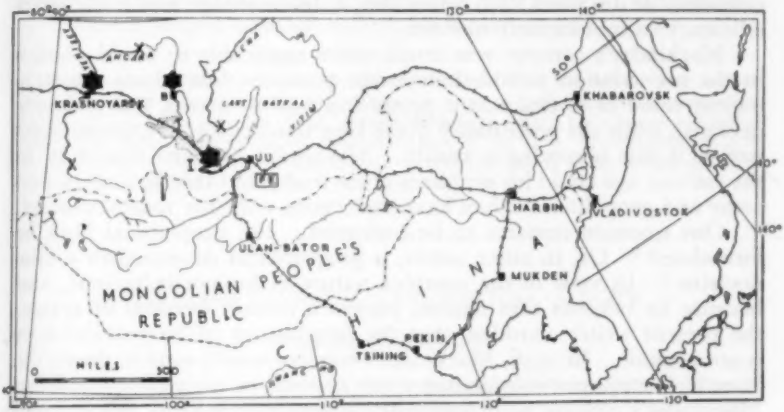

Fig. 2. Industrial Development in South-eastern Asia.

★ H.E.P. station—planned or under construction (Baranskiy) : X.—heads of river navigation (Izvestiya : 15.1.56 ; Pravda : 6, 11, 14.11.55) : shaded—Cheremkhovo coal-field : Fe.—iron ore deposit : I.—Irkutsk : UU.—Ulan Ude : B.—Bratsk.

trated ore. Further east the industrial production of the Kuznets Basin is to be expanded, partly with the aid of three new large power stations (Kamen' and Novosibirsk on the Ob', with a capacity of 500,000 kW each, Krasnoyarsk on the Yenisey with 3·2 million kW). Further east still another industrial base is to be established around the southern end of Lake Baykal, powered partly by the Bratsk hydro-electric power station on the Angara [17] (Fig. 2).

Some advantages are to be gained from the dispersal of heavy industry in the various Asiatic regions of the Union. Mining costs are said to be considerably lower in eastern Siberia.[18] If the Bratsk station lives up to its planned output of 22,000 million kWh [19] it will not only be the biggest hydro-electric power station in the world, but also far more efficient than most hydro-electric stations by virtue of its very high load factor. Furthermore, these new industrial areas can be considered safe from attacks by ground troops.

On the other hand, this economic policy entails serious and lasting disadvantages. Eastern Siberia can never hope to support a large

agricultural population, and forest exploitation notoriously gives rise to low densities of population. The markets for the industrial goods will therefore have to be sought outside the region. There is already one rail link to China across Mongolia and another line from Alma-Ata to Lanchow is to be finished under the current plan. The distances involved are continental in scale—from Ulan-Ude to Peking is about 1,200 miles. There is no equivalent in the Soviet Union to the Great Lakes system of North America. Even the projected navigation system to link Lake Baykal to the Northern Sea Route by the Angara and the Yenisey [19] would be handicapped by long periods of frost. If the Soviet Union is to become a large-scale exporter of industrial goods she will have to face the fact that most of her industrial areas lie at considerable distances from tide-water, a disadvantage which transport efficiency cannot entirely obviate.

Mackinder's concept was much more applicable to world politics in the pre-aviation period than at the present. Since 1904 the strategical value of distance as a protection against attack has seriously declined, while the potentiality of the Heartland power as a commercial nation is just becoming a reality. Mackinder believed that only in the railway age could his prophecy come true ; but that age has passed away and geopolitical values have undergone a further radical change.

One question remains to be answered : can geopolitical laws be formulated ? Or, in other words, is geographical determinism a false doctrine ? In view of the complex nature of human behaviour, and because he believes that nations possess a certain freedom of action, the present writer considers that the formulation of geopolitical laws is not possible. In 1956, Mackinder's concept would seem to doom the West to Communist subjugation ; yet it would be too easy to condemn Mackinder's concept as determinism and reject his ideas as a counsel of despair. It is well to remember that in 1919 he was anxious to warn the statesmen at Versailles of dangers hardly considered at that date ; his warning retains its value.

[1] Mackinder, H. J., during the discussion of his 1904 paper, The Geographical Pivot of History, *Geogr. Journ.*, 1904, 23, p. 421.

[2] Mackinder, H. J., *Democratic Ideals and Reality*, London, 1919, p. 141.

[3] Mackinder, 1919, p. 194.

[4] This fact is curiously ignored by Mackinder in The Round World and the Winning of Peace, *Foreign Affairs*, 1943, 21, p. 595.

[5] In the discussion of Mackinder, 1904. See also East, W. G., How strong is the Heartland ?, *Foreign Affairs*, 1950, 29, p. 78.

[6] Mason, K., Notes on the Northern Sea Route, *Geogr. Journ.*, 1940, 96, p. 27.

[7] Armstrong, T. E., The Northern Sea Route, *Geogr. Journ.*, 1955, 121, p. 136, and *The Northern Sea Route : Soviet Exploitation of the North East Passage*, Cambridge, 1954.

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[11] *The Resolutions of the 20th Session of the Communist Party of the Soviet Union*, 14th-25th February, 1956, p. 30 ff.

[12] *Radio Australia News*, 1/12/55.

[13] *Times Review of Industry*, November 1955, p. 98.

[14] Jackson, W. A. Douglas, The Virgin and Idle Lands of Western Siberia and Northern Kazakhstan ; A Geographical Appraisal, *Geogr. Rev.*, 1956, 46, p. 1.

[15] *Manchester Guardian*, 25/1/56.

[16] Harris, C. D., " Industrial Resources," Chapter 5 in Bergson, A. (Ed.), *Soviet Economic Growth*, New York, 1953, p. 163.

[17] Cole, J. P., A New Industrial Area in Asiatic U.S.S.R., *Geogr. Journ.*, 1956, 122, p. 354.

[18] The Soviet Communist Party's 20th Congress, in *World Today*, 1956, 12 (4), p. 134.

[19] Water Power and Irrigation in the U.S.S.R., *idem*, p. 152.

The events that have occurred in Eastern Europe since this article was written are reducing the cohesion of the Soviet bloc in terms of both intramural and extramural policies. The interests of the Soviet Union have ceased to be largely identical with the professed interests of the other members of the bloc. The implications of this change with regard to the distribution of political power in the world are very great, but the form they will take is still uncertain.

SCOTTISH MIGRATION STATISTICS : A NOTE

RICHARD H. OSBORNE

The centenary of the introduction of statutory registration of births, deaths and marriages in Scotland on the 1st of January 1855, has been marked by the publication of detailed statistics of natural increase and net migration during the past hundred years. The information is contained in special appendices to the two most recent Annual Reports of the Registrar-General for Scotland, for 1953 and 1954, while figures for the latest intercensal period, 1931-1951, are also presented in the General Volume of the 1951 Census of Scotland. The following note is based chiefly on these sources.

Between 1855 and 1954 there were striking changes in Scottish vital statistics. The average number of children per marriage fell from over 6 to 2·5, the birth-rate fell from 31 per thousand to 18 per thousand and the death-rate from 21 per thousand to 12 per thousand, with a consequent reduction in the rate of natural increase from 10 per thousand to 6 per thousand. The 1954 infant mortality rate, of 31 per thousand, was only one-quarter of that for 1855. The expectation of life for a male child rose from 41·9 years to 65·5 and that for a female child from 44·4 to 70·5. The number of persons under 15 years of age fell from 359 to 248 per thousand of the population, while the proportion of persons over 65 rose from 48 to 102.

A considerable redistribution of the population also took place, as Table 1 shows. Although the total population of Scotland increased from 3·0 millions to 5·1 millions, *i.e.* by about 72 per cent., the number of inhabitants declined in the Registrar-General's Northern and Southern Divisions of the country. The decline in the Northern Division was due to the fact that a fall in the population of the seven crofting counties (Argyll, Caithness, Inverness, Orkney, Ross and Cromarty, Sutherland, and Zetland) more than offset the increase in the remainder of the Division (Aberdeen, Angus—excluding the City of Dundee, Banff, Bute, Kincardine, Kinross, Moray, Nairn, and Perth). This latter area includes the coastal lowlands and sea-ports of the north-east. The decline of population in the Northern and Southern Divisions was accompanied by large increases in the industrialised East

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	1855		1954	
	Number	Per cent	Number	Per cent
Northern :	1,021,000	34·3	998,000	19·5
Crofting Counties . . .	388,000	13·0	281,000	5·5
Remainder	633,000	21·3	717,000	14·0
East Central	689,000	23·1	1,434,000	28·0
West Central	995,000	33·4	2,438,000	47·6
Southern	273,000	9·2	254,000	5·0
Scotland	2,978,000	100	5,124,000	100

TABLE 1.—DIVISIONAL REDISTRIBUTION OF POPULATION, 1855-1954

Central (Clackmannan, City of Dundee, Fife, the Lothians—including Edinburgh, and Stirling) and West Central (Ayr, Dunbarton, Lanark—including Glasgow, and Renfrew) Divisions, where population more than doubled and where the combined percentage holding of the national population rose from 56·5 to 75·6. By contrast the combined holding of the seven crofting counties and the seven counties forming the Southern Division (Berwick, Dumfries, Kirkcudbright, Peebles, Roxburgh, Selkirk, and Wigtown) fell from 22·2 to 10·5 per cent. This redistribution was effected by migration movements and by regional differences in the rate of natural increase—differences resulting to a large extent from the effect of migration on age-structure. The convergence on Central Scotland of immigrants from the North and the South has long been a feature of the birth-place tables published in the various census reports.

The Annual Reports for 1953 and 1954 contain tables showing the net balance of migration—*i.e.* the difference between total change and natural change—for each county and for Scotland as a whole in the eight intercensal periods between 1861 and 1951. Separate statistics are not given for the four cities, however. While the 1953 Report contains the more extensive commentary the 1954 Report contains the more detailed statistics, since it gives natural increase figures for each of the hundred years, 1855-1954, and also presents revised county migration balances for the periods 1911-21 and 1931-51 which make allowance for deaths in the two World Wars.

Between 1861 and 1901 only five counties made a net gain of population by migration. These were Lanark, including Glasgow—163,000 ; Dunbarton, adjoining Glasgow—16,000 ; Midlothian, including Edinburgh—47,000 ; Selkirk—800 ; and Bute—400. Selkirk's small population had been affected by the expansion of the woollen-textile town of Galashiels, while Bute, consisting of the islands of Bute, Arran and the Cumbraes in the Firth of Clyde, had become a popular county for holidays and retirement. Twenty-three of the remaining twenty-eight counties, headed by Aberdeen and Ayr, each lost between 10,000 and 80,000 persons by migration, and in all twenty-eight counties the net loss amounted to more than 10 per cent of the 1861 population.

Between 1901 and 1951 only Bute registered a net gain of 2,500. Twenty-two counties, headed by Lanark—including Glasgow (437,000) and Aberdeen—including Aberdeen City (108,000), lost over 10,000 persons each, while in thirty counties the loss exceeded 10 per cent of the 1901 population. Unlike the predominantly rural counties the industrial counties had higher migration losses in the period 1901-1951, when industry and coal-mining were affected by periods of economic depression, than in the period 1861-1901, their heaviest losses occurring for the most part in the decade 1921-31. The change in the status of Lanark, from the county with the largest gain to the county with the largest loss, reveals the inability of Scotland's major industrial area to provide adequate and sufficiently attractive employment during the past half-century to retain its natural increase of population.

Over the whole ninety-year period, 1861-1951, the only counties which experienced a net inward movement of population were Bute (2,900), Dunbarton (3,600), and Midlothian (1,100). The remaining thirty counties all lost population

on balance to the rest of Scotland and to other countries, the largest numerical losses being those of Lanark (274,000) and Aberdeen (187,000). Some of the less populous counties had higher rates of loss, however, if their net balances are expressed as percentages of their 1861 population ; in fact Lanark's rate of loss was the fourth lowest.

Losses by migration resulted in a decline of population in fifteen counties between 1861 and 1951. These all lie north or south of the central industrial zones. The numerical decreases range from under 1,000 in Kinross to over 20,000 in Ross and Cromarty, while the percentage decreases vary from 4 per cent in Perth to 45 per cent in both Caithness and Sutherland. It is interesting to note that sixteen counties, all mainly agricultural in character, attained their maximum population before 1901 and that the heaviest migration losses from twenty counties also occurred before 1901. Eighteen counties increased in population between 1861 and 1951, the largest increase being nearly one million in Lanark, followed by increases of between 100,000 and 300,000 in Ayr, Dunbarton, Fife, Midlothian, and Renfrew. The 1951 population of Dunbarton was over three times its population in 1861, while that of Lanark was two and a half times the 1861 figure.

	Natural Increase	Total Increase	Net Emigration	Per cent of popn. at beginning of period
1861-71	416,285	297,724	118,561	3·9
1871-81	468,793	375,555	93,238	2·8
1881-91	507,864	290,074	217,790	5·8
1891-1901	499,811	446,456	53,355	1·3
1901-11	542,893	288,801	254,092	5·7
1911-21	434,189	121,593	238,596*	5·0
1921-31	352,386	−39,517	391,903	8·0
1931-51	536,294	253,435	220,000*	4·5
1861-1951	3,758,515	2,034,121	1,587,535	51·8

TABLE 2.—NET EMIGRATION FROM SCOTLAND, 1861-1951

* After allowance for 74,000 overseas war deaths in First World War and 34,000 in Second World War and for larger numbers serving in Armed Forces outside Scotland in 1951 compared with 1931.

	Net Loss 1861-1951	Per cent. of 1861 popn.	Per cent loss or gain	
			1861-1901	1901-1951
Northern Division :				
Crofting Counties	238,000	62·6	−39·4	−25·0
North East . .	501,000	70·2	−34·3	−29·2
Central Divisions* .	662,000	39·1	+2·8	−23·8
Southern Division .	188,000	68·7	−48·2	−21·3
Scotland . .	1,589,000	51·8	−15·8	−24·7

TABLE 3.—REGIONAL NET MIGRATION, 1861-1951

* Central Divisions here include Bute.

The net gains by migration experienced by individual counties in the last ninety years (amounting to some 7,600 persons absorbed by Bute, Dunbarton, and Midlothian) were, of course, quite insufficient to offset the continual losses by migration from the rest of the country. Scotland as a whole, therefore, experienced an adverse balance of migration with the rest of the world in each of the intercensal periods under review. The chief destinations of emigrants were England, the Commonwealth, and the U.S.A. Table 2 shows the intercensal net losses since 1861, together with contemporary natural increase figures and the percentage ratios of net migration

to the population at the beginning of each period, while Table 3 shows the regional contributions to these migration losses. Here an outstanding feature is the full participation of Central Scotland in the overall loss from the country since 1901, compared with its rôle as a region of net gain between 1861 and 1901.

The figures in Table 2 reveal that after allowance is made for overseas war deaths Scotland suffered a net loss of about 1,590,000 persons between 1861 and 1951 —equivalent to more than one-half of the 1861 population of the country. The net loss between 1861 and 1901 amounted to 483,000, equivalent to rather more than the present population of Edinburgh and representing 16 per cent of the 1861 population, while the net loss between 1901 and 1951 amounted to 1,105,000, equivalent to rather more than the present population of Glasgow and representing 25 per cent of the 1901 population. The Registrar-General is of the opinion that if all these persons had been retained in Scotland the present population would now be over seven millions. He also points out that, curiously enough, Scotland's loss is almost exactly equal to the figure of 1,586,000 which has been calculated as the net loss from England and Wales during the same period. The point is, however, that the population of Scotland in 1861 was about one-seventh of that of England and Wales, so that the relative impact of emigration losses has been very much heavier in Scotland. The check on population growth resulting from this heavier rate of loss is shown by the fact that the population of Scotland is now only one-ninth of that of England and Wales.

The net loss from Scotland to England and Wales has increased considerably since 1911. The loss amounted to 10,000 in the period 1911-21, 63,000 in 1921-31, 32,000 in 1931-41, and 177,000 in 1941-51, the cumulative total being 282,000—equivalent, it may be noted, to the present population of the city of Leicester. The total migration loss for the period 1911-51 is estimated at 850,000, the balance of 568,000 being accounted for by the loss to overseas countries. Table 4 analyses the estimated total loss between 1931 and 1951 and shows the net gain from overseas which occurred during the 1930s, when many emigrants returned to Scotland.

	Overseas	England & Wales	Total
1931-45	+77,000	−116,000	−39,000
1945-51	−88,000	−93,000	−181,000
1931-51	−11,000	−209,000	−220,000

TABLE 4.—NET MIGRATION, 1931-1951

It will be seen that migration from Scotland in the period 1931-51 was both numerically and proportionately lighter than in the previous three decades, even without making any allowance for the doubling of the length of the intercensal period. This improvement might well be considered as evidence of conditions of fuller employment since 1939, but an important factor, according to the Registrar-General, was undoubtedly the absence of a net loss of population to overseas countries between 1931 and 1945. This resulted from discouraging economic conditions abroad and later from the restrictions caused by the war. The overseas loss of 88,000 in the six years 1945-51 is therefore viewed with some concern, as is also the continued drift of population southwards to England, which totalled 93,000 (excluding returning evacuees) in the same period. In conjunction with the fairly modest rate of natural increase these losses mean that the annual increase in total population is only several thousands. In 1955, for instance, natural increase was 29,000 and net emigration 23,000—10,000 to overseas countries and 13,000 to England and Wales—so that the total increase in population was only 6,000.

The lower rate of net migration loss during the years 1931-51, compared with 1921-31, was accompanied by a reduction in the volume of net loss sustained by individual counties. Although only eight counties recorded a net gain by migration between 1931 and 1951 (Argyll, Ayr, Bute, Clackmannan, Dunbarton, Midlothian, Perth and Renfrew), only five of the remaining twenty-five suffered a greater loss than in the ten-year period 1921-31 (Banff, Caithness, Lanark, Selkirk, and Sutherland), and in only one (Roxburgh) was a gain replaced by a loss.

Only ten counties were depopulated in the last intercensal period, compared with twenty-eight in the period 1921-31. These were Banff, Berwick, Caithness, Kinross, Orkney, Ross and Cromarty, Roxburgh, Selkirk, Sutherland, and Zetland. On the whole these counties have very little industry, except for Roxburgh and Selkirk, with their important textile activities, and most of them were affected by a chronic excess of deaths over births in the 1930s. This resulted from the ageing of the population—related to previous emigration—and also, in the three Border counties, from the regional characteristic of exceptionally low fertility rates. In recent years there has been some reassertion of this tendency to negative natural change in these counties.

	Total Change	Net Migration	Per cent of 1931 popn.
Northern . .	+2·6	−34,300	−3·5
Crofting Counties	−2·2	−8,500	−2·9
East Central . .	+8·6	−10,000	−0·8
West Central . .	+4·8	−167,100	−7·2
Southern . .	+1·5	−8,600	−3·4
Scotland . .	+5·2	−220,000	−4·5

TABLE 5.—DIVISIONAL POPULATION CHANGES AND NET MIGRATION, 1931-51

Table 5 showing regional losses between 1931 and 1951 reveals a marked difference in rate of loss between the East Central and West Central counties. For the narrower Edinburgh region, *i.e.* the Lothians and Fife, there was actually a small gain of 1,000—a figure resulting from gains by Edinburgh and the rest of Midlothian (10,200 and 700), and losses from East and West Lothian (1,300 and 8,100), and from Fife (500). West Lothian was affected by the decline of coal and oil-shale mining. The loss from the West Central counties is made up of losses from Glasgow and the rest of Lanark (122,000 and 50,600) and relatively small gains by Ayr, Dunbarton, and Renfrew (2,400, 900, and 2,200). It seems possible that the current expansion of coal-mining in Fife and Midlothian and the continued attraction of Edinburgh as a residential and business centre may well favour a persistence of this lead of the Edinburgh region over the Glasgow region with respect to migration. New industrial employment is continually being provided in the Glasgow region, however, and there is also the fact that the migration of coal-miners from Lanarkshire to the eastern fields has not been fulfilled to the extent formerly anticipated.

Finally, Table 6 shows estimated net migration, after allowance for war deaths and other factors, overall percentage change, and enumerated 1951 population in the four cities and thirty-three counties of Scotland in the period 1931-51. The migration figures supersede those suggested earlier in the city and county volumes of the 1951 census. Separate figures for the twenty "Large burghs" are also shown in this table. It will be seen that there is not a very close connection between net migration and percentage change. This is chiefly due to the varying population size of the cities, counties and large burghs, and to wide variations in local rates of natural increase. The most obvious discrepancy in the counties occurs in Moray and results from the fact that a large increase took place in the number of persons in Defence Establishments in this county. Changes in the local strength of Service personnel between the two census dates are excluded from consideration in the migration estimates.

Of the four cities only Edinburgh is considered to have experienced a net gain by migration during the period under review. Aberdeen remained virtually in balance, with only a negligible loss, while both Dundee and Glasgow registered considerable losses. These were probably due both to normal 'overspill' developments and to unfavourable economic conditions in the 1930s, connected with depression in the Dundee jute industry and in the shipbuilding and other heavy engineering industries of Clydeside.

Large increases took place on the outskirts of Glasgow, the combined population of the New Kilpatrick District of Dunbarton, the First District of Renfrew and the Ninth District of Lanark increasing from 76,500 to 115,000. It is plain,

TABLE 6.—NET MIGRATION AND POPULATION CHANGE, 1931-51

CITIES, COUNTIES AND LARGE BURGHS

	Estimated Net Migration	Overall Change	Population 1951
CITIES :—			
Aberdeen	−800	+7·6	182,729
Dundee	−11,900	+0·1	177,340
Edinburgh	+10,200	+6·3	466,761
Glasgow	−122,000	−0·3	1,089,767
LARGE BURGHS :—			
Arbroath	+1,200	+10·2	19,511
Ayr	+300	+8·9	42,377
Kilmarnock	−1,300	+8·9	42,123
Dumfries	+1,500	+14·4	26,322
Clydebank	−8,100	−5·1	44,638
Dumbarton	−800	+8·9	23,702
Dunfermline	+3,700	+27·6	44,719
Kirkcaldy	+900	+9·6	49,050
Inverness	+2,100	+19·4	28,107
Airdrie	−1,700	+13·4	30,313
Coatbridge	−4,600	+9·3	47,541
Hamilton	−4,900	+5·4	40,174
Motherwell & Wishaw	−8,100	+3·9	68,154
Rutherglen	−1,800	−3·8	24,213
Perth	+3,300	+15·5	40,487
Greenock	−13,100	−3·4	76,292
Paisley	−5,800	+6·0	93,711
Port Glasgow	−2,900	+9·0	21,618
Falkirk	−2,700	+2·7	37,535
Stirling	−500	+9·8	26,962
COUNTIES (EXCL. CITIES BUT INCL. LARGE BURGHS) :—			
Aberdeen	−19,400	+0·8	144,800
Angus	+1,500	+4·9	97,536
Argyll	+2,900	+0·5	63,361
Ayr	+2,400	+12·6	321,237
Banff	−11,100	−8·7	50,148
Berwick	−1,800	−5·8	25,068
Bute	+2,100	+2·4	19,283
Caithness	−4,100	−11·5	22,710
Clackmannan	+2,000	+17·5	37,532
Dumfries	−1,000	+5·5	85,660
Dunbarton	+900	+12·0	164,269
East Lothian	−1,300	+10·4	52,258
Fife	−500	+11·0	306,778
Inverness	−100	+3·4	84,930
Kincardine	−1,200	+4·1	27,882
Kinross	−200	−0·5	7,418
Kirkcudbright	−1,800	+1·8	30,725
Lanark	−50,600	+6·1	524,596
Midlothian	+700	+13·4	98,974
Moray	−400	+18·2	48,218
Nairn	−200	+5·1	8,719
Orkney	−1,100	−3·7	21,255
Peebles	−100	+1·2	15,232
Perth	+3,900	+6·0	128,029
Renfrew	+2,200	+12·7	324,660
Ross and Cromarty	−3,300	−3·6	60,508
Roxburgh	−500	−0·3	45,557
Selkirk	−600	−4·3	21,729
Stirling	−1,100	+12·7	187,527
Sutherland	−1,800	−15·1	13,670
West Lothian	−8,100	+6·8	88,577
Wigtown	−2,800	+7·8	31,620
Zetland	−1,000	−9·7	19,352
Scotland	−220,000	+5·2	5,096,415

nevertheless, that any inward migration element in this increase could do little to compensate for Glasgow's net loss of 122,000, especially when it is remembered that these areas are close to other industrial towns within the Central Clydeside conurbation which likewise lost population by migration.

Among the counties there were losses of over 2,000 from the largely agricultural counties of Aberdeen, Banff, Caithness, Ross and Cromarty, and Wigtown, and also from the largely industrial counties of Lanark and West Lothian. Gains of over 2,000 were recorded by Argyll, Ayr, and Bute, which contain residential towns and resorts on the shores of the Firth of Clyde, Clackmannan, which has been affected by new coal-mining developments, Perth, where the county-town has shown considerable expansion, and Renfrew, with new suburban areas close to Glasgow.

It will be seen from the table that the industrial towns of Clydeside all suffered migration losses. These are probably related to economic depression in the 1930s, the effects of which had not, at the time of the recent census, been offset—demographically—by subsequent economic rehabilitation. This group consists of Clydebank, Dumbarton, Airdrie, Coatbridge, Hamilton, Motherwell and Wishaw, Rutherglen, Greenock, Paisley, and Port Glasgow. Of the remaining towns with an important industrial element Kilmarnock, Falkirk, and Stirling lost population and Arbroath, Kirkcaldy, and particularly Dunfermline, which contains within its boundaries the naval base of Rosyth, gained population. The remaining four burghs which gained population are the county towns of Ayr, Dumfries, Inverness, and Perth, which have all, in varying degree, experienced local industrial growth. It should be noted that only three of the industrial towns which lost population by migration—Clydebank, Rutherglen, and Greenock—were actually depopulated and that the overall percentage increases in several of the remainder compare favourably with the rates for the towns experiencing migration gains. This latter fact can no doubt be attributed to differences in the respective rates of natural increase.

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THE BORDER FLOODS, AUGUST 1956

Observations and Comments

R. Common

Just over eight years ago the Border counties were ravaged by the floodwaters of swollen streams which left behind them a legacy of damage and destruction. Again, in the late summer of 1956 similar, though fortunately less spectacular, events have occurred. As in 1948 it was the receipt of heavy and sustained rainfall in the catchments of the rivers Tyne, Eye, and Tweed that initiated the trouble. Once again the consequent flooding and damage by these and other streams in spate was the result of both natural and man-made causes.

Flooding occurred mainly on the 28th of August when available records indicate a peak rainfall of about 2 inches in 24 hours generally, but in some localities up to 4 inches compared with 3 to 6 inches on the 12th of August 1948. The main flooding was followed by a minor one a week later, but neither appear to have been so serious as those which affected the Findhorn and Nairn valleys on the 30th and 31st of July 1956. However, since the rainfall was not so concentrated on this occasion the excessively high rates of stream discharge were not maintained, and further damage was thus checked. Nevertheless, as a reconnaissance of the area afterwards showed, a very considerable amount of water remained on the land to aggravate further the problems of a particularly wet and dull harvest season. This water-sodden land, like the damaged telephonic communications formed an important, although less conspicuous, part of the scene.

Since the National Press was commendably prompt [1] and thorough, at the time, in photographing and reporting the floods, only a tabulated summary is now provided to record the main events which occurred.

Summary of Events, August 1956

TYNE BASIN : At Haddington the river rose *c.* 12 feet overflowing its low banks and damaging house property and a grain mill. Below East Linton the floodplain was locally covered by floodwater affecting crops.

EYE BASIN : Estimated rise of floodwater was *c.* 8 feet in parts of the catchment. At Grantshouse railway station the river broke through low banking at a point of weakness. Slope failures on railway embankment and flooding of short stretches of railway and road occurred north of Grantshouse. Between Grantshouse and Reston haughland was locally flooded. Eyemouth harbour and lower part of the village was affected by flooding because of a unique combination of natural and man-made causes.

TWEED BASIN : At Berwick the Tweed rose *c.* 16 feet over the peak discharge period. Up valley to Coldstream physiography of the valley restricted the spread of water so that only pasture and crops were affected generally. However, the lower part of Norham village was flooded. Between Coldstream and Wark the stream tract and floodplain favoured more extensive flooding, whereas between Wark and Kelso only restricted stretches of haughland were water-covered. At Kelso the Teviot-Tweed confluence area was inundated, and here it was estimated that the flood waters rose 8 feet above normal. Above Kelso there was local flooding of lowlying haughland (e.g. N. of Drumelzier), the extent of flooding naturally being greatest at tributary confluence points—crops and pasture affected chiefly.

TWEED TRIBUTARIES : The Whiteadder and Blackadder followed the pattern of the 1948 floods but on a smaller scale. However, mills at Cumledge and Chirnside again were affected. The middle and lower tracts of the Teviot, Leithen, Eddleston, Gala and Till suffered local inundation and town property at Hawick, Galashiels, Peebles and Melrose were affected. In the Jed basin, the site of Jedburgh suffered most because of its unfortunate position, having the hill catchment nearby, the deeply incised valley tract southwards and the development of a low flood plain on the north side of the town. The Tyne, Eye and Tweed all carried greatly enlarged loads in suspension during and after the flood period, causing discolouration 1-2 miles out to sea.

TRANSPORT AND COMMUNICATIONS : Blockages on the railway line in the Cockburnspath-Grantshouse stretch necessitated traffic diversions. Roads were temporarily flooded at sites between Kelso and Berwick, Kelso and Wooler, Berwick and Wooler ; floods in the Leader and Upper Tweed valleys also caused traffic diversions for a time. Telephonic communications appear to have been worst affected in the middle stretch of the Tweed valley.

D. M. Smith : Photo News Service : Berwick

Pl. 1a. EYEMOUTH HARBOUR

Flood waters of the River Eye pouring into harbour and swamping small craft.

Pl. 1b. SOUTHERN END OF EYEMOUTH HARBOUR SHOWING SITE WHERE STREAM BLOCKAGE OCCURRED

Tree trunks are part of debris which blocked sluice gate (left) into harbour and Eye diversion channel (right).

Pl.2. TAY VALLEY, NEAR DUNKELD, PERTHSHIRE

Valley incised into *Lower Grampian Surface* (here *c.* 1,400-1,600 ft.) which on higher, rockier ground (left) carries dry moorland, on more favourably exposed slopes (right mid-distance) some of highest arable land in Scotland. Above *Main Grampian Surface* (*c.* 2,000-2,500 ft.) in background, volcanic mass of Ben Vrackie (centre) rises to 2,757 ft. and multiple quartzitic peaks of Beinn à Chlo (right) to 3,671 ft. River meanders across alluvia filling a valley over-deepened by glacial erosion; steep, rocky sides largely wooded. Flood plain liable to flooding; cultivation, settlement and communications confined to fringing terraces. This extensive enclave of cultivation formed basis for a considerable population whose chief, the Duke of Atholl, sitting astride a major route way in Blair Castle (upstream), was a powerful element in Scottish history. The nodal quality of region now manifest in town of Pitlochry.

Photo by Aero films Ltd.

On the other hand, some of the particular observations made subsequently in the area merit further attention. The Cockburnspath-Reston 'through valley' may be considered first. This is a natural cutting through the Lammermuirs which is, paradoxically, both an asset and a liability. Its value to transport and communications lies in its directness, its snow-free character in winter and its comparatively easy gradients, but these benefits tend to be offset by its drain-like character. Emerging from an upper basin at Grantshouse the modest waters of the Eye turn abruptly down part of this old valley[2] and normally meander freely towards Reston. However, in time of spate the river spills over the flat valley floor at and below its turning point, and it is this unfortunate habit which necessitates either protective works or avoidance by man. Also near Grantshouse there is a very indeterminate water parting in the valley floor (a corrom ?) so that artificial aids are needed to divide north-west from south-east flowing water.

Where and why did failures again occur in this locality during the recent floods ? At Grantshouse the river broke out on to the railway track and floodplain east of the railway station where a protective shield of steel piles, erected after the 1948 floods, ended. Further north, beyond Penmansheil Tunnel, part of the slope of the railway cutting slipped, almost as in 1948, when a siphon under it was unable to cope with the spate waters of the Pease Burn ; this burn is usually small and possesses a catchment basin of less than three square miles. Alongside the adjacent Aikieside Woods, water apparently rose, over-topped a stone-lined drainage channel and the railway track and then scoured out railway ballast before finally breaching a retaining wall. As with the Grantshouse site this failure occurred where artificial protection (*i.e.* the stone-lined channel) ended and water passed on to a natural tract.

Eyemouth harbour lies at the seaward end of a narrow linn and by dint of considerable ingenuity is normally safe and sheltered. This security is partially achieved by the channelling of the water along and outside the east wall of the harbour and also by the provision of a sluice gate between the river and the harbour. Unfortunately during the recent spate the river was ponded-up behind a pile of debris which had fouled the sluice gate and the intake of the diversion channel (Pl. 1b). Eventually it flooded the lower part of the adjacent village and poured over into the harbour itself (Pl. 1a). With an advance warning system some precautions could have been taken in the harbour area and indeed the presence of a sieve-like trap upstream could have inhibited the collection of debris at such a vulnerable site.[3]

Haddington may be considered next, as a town unfortunately subject to river flooding. On this occasion the Tyne floodwaters again damaged property in the east end of the town, easily overflowing the low banks above the weirs and bridges, but below the lower bridge spreading over the right bank alone. Three observations on the flooding problem here can be made : first, it was clearly seen, below the lower bridge, that a good solid frontage to the river was an insurance against flooding on the left bank (as with the Tweed at Kelso)[4]; second, it was noted that the abrupt bend eastwards in the river, beyond the town, needed protection as a long-term check on river erosion ; finally, it seems reasonable to suggest that in this town a stretch of badly needed river defence works could also be profitably used for amenity purposes. Civil engineers are in fact now investigating the effects of weirs and other structures in the river for the Town Council. Similarly, the East Lothian Planning Department are at present actively concerned about the Tyne's unfortunate habits. Elsewhere in the area the field reconnaissance showed that damage by flooding resulted from causes which have already been dealt with at length in previous articles[4] and it would be pointless repetition to enumerate them. But it is worth commenting on the general lack of debris slides on the hill slopes over the whole area on this occasion, their place as noteworthy phenomena being taken by numerous active 'well-eyes' or flushes from which water poured. This water usually only presented a nuisance at the time to transport and communication.

It is considered more important, at this stage, to suggest what might be done by the community and individuals to help themselves and the authorities. In the first place a comprehensive record of each successive flood should be made with details on its extent, damage, and possible causes provided. Obviously the regional unit for co-ordinated work must be the major river basin, regardless of administrative boundaries, subdivided in turn into minor tributary basins. Within each of these basins selected bridge points could be fitted with simple gauging staffs so that the

readings there might be absolute and objective. Similarly the measurement of stream cross sections and the periodic use of current meters at key gauging sites are also advocated. An inventory of the available rain gauges present within a catchment should be made, gaps in the coverage rectified, and then the help of schools, local societies, public and private bodies sought in collecting records of rainfall and stream discharges. With such a long-term project the data concerning stream behaviour in the catchment would then be forthcoming and a second need satisfied. Simultaneously the more academically minded could turn to existing historical records to seek information on past floods for tabulation, mapping, and evaluation. As for the landowner or farmer whose fields are being gnawed away by running water or smeared with coarse infertile deposits, he in turn would do well to recall the need for constant maintenance of stream banks and even to think of trying suitable small-scale conservation techniques, the value of which have been proved elsewhere.[5] For it must now be painfully clear that the correct line and order of preventative action to curb our Scottish rivers will be possible only when sufficient interest is aroused, the relevant information collected and appraised, and when co-ordinated legislation, adequately financed, is enacted.

The author's thanks are due to Professor R. Miller for his general suggestions and help with the article, to Miss A. Thomson for photography, and to Mr F. M. Spaven for the additional information he provided and for his general comments on this report.

[1] See *The Scotsman* and *The Times*, 29th August 1956.

[2] Even a superficial examination of the map of the area bounded by the North Sea, Cockburnspath, Longformacus, Chirnside, and Burnmouth will demonstrate that numerous glacial derangements of the drainage pattern have occurred (see 1-inch map O.S. Sheet 75).

[3] Whilst visiting Greece in 1955 the author inspected a simple type of river-work which might lend itself to this and comparable situations. Lengths of old railway line had been driven vertically into the ground to form double rows extending out from either bank of the river. Under normal conditions only some of these uprights were in the water, but under high water conditions they certainly must trap considerable quantities of vegetation, so obviating blockages downstream.

[4] Ogilvie, A. G. Co-operative Research on S.E. Scotland. *S.G.M.*, 1952, 68 (1) : 22.

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[5] See for example H. H. Bennett, *Soil Conservation*, Chaps. 18-26, pp. 419-557. New York, 1939.

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ALBERT AND JULIANA : TWO GREAT WATERWAYS

F. J. MONKHOUSE

THE river Meuse, with a total length of about 560 miles, rises in France on the northern slopes of the Plateau de Langres and flows northwards through the scarplands on the eastern margins of the Paris Basin. For some eighty miles the river is entrenched in a winding steep-sided valley cut in the western slope of the Côtes de Meuse. After crossing the Liassic Clay Vale between Sedan and Mézières in a series of great loops, it continues its course across the Ardennes into Belgium, flowing as far as Namur in a narrow, often gorge-like valley some three to five hundred feet below the monotonous level surface of the plateau. At Namur the river undergoes a marked change of direction as it enters the west-south-west to east-north-east line of the ' coalfield furrow ' which flanks the northern edge of the Ardennes uplands ; it follows, in fact, the trend of its tributary, the Sambre, coming in from the west. Below Liège the river flows northwards for about a hundred miles, and finally it sweeps westwards in an arc to enter the North Sea in a vast composite estuarine region, jointly built up by the Scheldt (*Schelde* or *Escaut*), the Meuse itself (known as the *Maas* in Flemish Belgium and in the Netherlands) and the several Rhine distributaries.

The Meuse valley below Liège has been profoundly affected by several past changes in the course and the base-level of the river, although these are too complex to consider in detail here. The net result has been the formation between Liège and Maasbracht of a relatively steep-sided valley, some two miles broad, bounded on the east by the dissected Cretaceous plateau of South Limburg, while to the west lies the more or less continuous line of the Hesbaye-Kempenland-Peel plateaus.

There is one important feature of the Kempenland plateau which was to affect the actual development of the waterway pattern. A right-bank tributary of the Scheldt, the Demer, has eroded a marked west-east ' furrow ' along the southern margin of this plateau, in which lie such towns as Hasselt and Diest. At the eastern end of this furrow is a ' neck ' of land just exceeding 300 feet above sea level, which narrowly links the Kempen plateau in the north with the Hesbaye plateau in the south. This ' neck ', in fact, separates the Meuse drainage system from that of the Scheldt, and it will be seen later that it formed the major physical obstacle to the construction of the Albert Canal.

It will be appreciated that the Meuse is an international river, both in a geographical sense and in international law. The river rises in France and forms a navigable French waterway for 170 miles, then crosses the frontier into Belgium, just below Givet. For a further eighty-four miles, as far as Lanaye, it is wholly Belgian, but from there for about fifty miles to near Maasbracht, with one important exception, the

frontier between the two countries runs along the centre of the river. Below Maasbracht, of course, it flows wholly in Dutch territory, a distance of about 133 miles to Geertruidenberg, where the estuary officially begins. The one exception referred to is in the Maastricht district, where the town of that name stands mainly on the left bank of the river, while the frontier makes a loop some two and a half miles further to the west on to the Hesbaye plateau. For a crucial distance of about seven miles, therefore, both banks of the river are Dutch.

The joint results of the geographical fact of a prominent plateau-edge bounding the Meuse valley on the west, and of the political fact that Dutch territory extends at one point to the west of this plateau-edge, were to have profound effects on the pattern of waterways ultimately created.

The Navigation of the Meuse

The Meuse cannot be called a good natural waterway, yet because of its European location considerable efforts have been made to utilise it as effectively as possible. In France the river has been regularised from Troussey, where it is linked to the Marne-Rhine Canal, as far as the Belgian frontier ; for much of this length it has been canalised and in effect incorporated into the northern section of the Canal de l'Est ; numerous meanders have been cut through, and four tunnels have actually been necessary. The catchment area of the upper Meuse is limited, mainly as the result of the capture of some of its headstreams by its more active neighbour, the Moselle. As a result, the water-supply is not wholly adequate ; the bed has therefore been deepened by dredging, and no less than fifty-nine locks constructed in order to maintain an effective depth of seven feet, particularly necessary during the period of summer low-water.

Despite these difficulties, the French section of the Meuse carries well over two million tons of freight each year, including coal, iron-ore, pit-props, building-stone and bricks. Moreover, there is a useful trans-frontier traffic ; in 1954 about 0·6 million tons of freight moved from Belgium into France, while about 0·5 million tons passed in the opposite direction.

After the Meuse enters Belgium, despite some difficult sections through the Ardennes it is effectively navigable as far as Liège ; from that town to the frontier near Lanaye it is little used. The river in Belgium has a very variable régime, much more so than the upper French portion, as a result of its receiving numerous torrential Ardennes tributaries, such as the Lesse. Below Namur, in fact, the flow may vary from thirty-five cubic metres per second at low water to as much as 3,000 cubic metres per second at flood. Since about 1852 the Belgian government has carried out a series of regularisation schemes, and has constructed twenty-one locks, sluices and stabilising barrages in an effort to maintain an adequate navigational depth ; this however still fluctuates from seven to nine feet. The virtual limit of downstream navigation is the Monsin barrage just below Liège, completed in 1930, near where the Albert Canal branches off. The regularised river is now

navigable to barges of from 1,350 to 2,000 tons between Liège and Huy, and to barges of from 450 to 1,350 tons further upstream between Huy and Namur, while the Ardennes section from Namur to the French frontier can accommodate the characteristic *péniche* of 275 to 450 tons.

The Meuse is joined at Namur by the Sambre, which affords fifty-eight miles of navigable waterway in Belgium, as well as an upper thirty-four miles in France. A navigational depth of about seven feet is maintained by means of thirty-one locks, and work is in progress to improve still further the section of the river between Namur and Charleroi, which traverses the important industrial region.

Some indication of the navigational importance of the two rivers within Belgium is provided by the fact that the Meuse carried over twelve million tons of freight in 1954, the Sambre another five million tons, mostly coal, iron-ore and building-stone. Thus these waterways contribute appreciably to the industrial life of the Charleroi-Namur-Liège industrial region. It will be seen therefore that from Troussey in eastern France downstream to Liège in Belgium the Meuse is continuously navigable, although admittedly for larger barges only in the lowest section between Huy and Liège.

Below Maasbracht the Meuse [1] flows wholly within Dutch territory to the sea. The great port of Rotterdam is not situated on the actual estuary of the Meuse itself, but on the New Maas, the estuary of the Lek. Nevertheless, the present-day network of interconnecting channels between the Meuse, Waal and Lek is so adequate that in actual fact Rotterdam can be regarded in some respects as being situated at the seaward end of the Meuse system, in other words, that the Meuse basin lies in the hinterland of Rotterdam.

The Netherlands is therefore concerned no less than Belgium with the overall problem of Meuse navigation. Furthermore, the improvement of Meuse navigation downstream from Maastricht must obviously assist the economic development of the province of South Limburg, which is relatively rather remote from the main part of the country, and particularly in the exploitation of the South Limburg coalfied (Fig. 1), the sole Dutch field as yet worked.

The regularisation of the lower Meuse by the Dutch is a long story which can be summarised only briefly. After the failure of the two countries, in the years following the Treaty of Versailles, to agree upon measures to be adopted in the improvement of the international section, the Dutch decided to take independent action on their own section, both to improve the river's navigability and to assist in flood control. The necessity of the latter was sharply emphasized by the disastrous floods of the winter of 1926-27, when the river dykes burst at a number of points and extensive areas of land were inundated. The river is now contained between vast embankments, several large meanders have been cut through, and five barrages with locks have been built to stabilise the depth of water. Below Mook the Meuse flows in close proximity to the Waal, and the inter-riverine area was for centuries the scene of extensive flooding. The rivers are now separated by dykes, and locked connections have been established where the rivers approach, as at St. Andries where the locks will take 2,000-ton barges. In 1928

the Maas-Waal Canal, eight and a quarter miles long, was built to link the Maas at Mook with the Waal below Nijmegen, involving locks to accommodate 2,000-ton barges at either end. This now forms the most important and direct link between the Meuse navigation and Rotterdam. The outcome of all these schemes, completed just before the war of 1939-45, was to enable the Meuse below Maasbracht to accommodate vessels of at least 1,500 tons, and as a result of post-war dredging and further improvement the river can now normally be negotiated by 2,000-ton barges.

It will be appreciated, however, that these measures described were concerned with the Meuse below Maasbracht, where it becomes wholly a Dutch river. From Lanaye to Maasbracht, with the exception of the short stretch through the city of Maastricht, the frontier runs along the centre of the river. Its course is impeded by gravel- and sand-banks, islets and backwaters, but with Belgian unwillingness to undertake any joint regularisation, unilateral action by the Netherlands has been obviously impossible.

The chief port of Belgium is Antwerp, which stands on the right bank of the Scheldt estuary ; in the words of the old Belgian proverb, " Antwerp owes the Scheldt to God, and everything else to the Scheldt." To this estuary drain the upper Scheldt and its various tributary streams of the Lys, Dendre and Demer, and on it converges a large part of Belgium's system of inland navigation. The significance of this is emphasized by the facts that the length of the Belgian network of waterways totals as much as one-third of that of the rail-net, and that waterborne freight amounted to no less than 33·6 million tons in 1954, or about a third of the railborne total.

But not all these waterways are focused directly on Antwerp ; the exception is the Sambre-Meuse system already described, along which is strung out the chief industrial area of Belgium, and yet which is separated from the Scheldt waterways and Antwerp by the Brabant, Hesbaye and Kempen plateaus. What is more, this heavy industrial area is mainly concerned with coal, coke, iron-ore, pig-iron, cement, glass-sands, chemicals and other bulky fuels and raw materials which can be conveniently and cheaply moved by water. For more than a century, then, Belgium has been concerned with the problem of a direct all-Belgian water-link between Antwerp and Liège, between Scheldt and Meuse, between the chief port and the chief manufacturing area. Conversely, Belgium has not been interested in the improvement of Meuse navigation below Lanaye, since this would mainly benefit the Netherlands in general and Rotterdam in particular. The Netherlands, on the other hand, has been anxious to see the Meuse become a great international waterway extending from eastern France and across southern Belgium, serving South Limburg and focusing on Rotterdam.

Thus both Belgium and the Netherlands had their problems. The solution ultimately achieved in the case of Belgium involved the construction of the Albert Canal, a direct all-Belgian waterway from Liège to Antwerp across the Meuse-Scheldt watershed, that is, over the Kempen plateau. In the case of the Netherlands the solution was the construction of the lateral Juliana Canal along the right bank of the

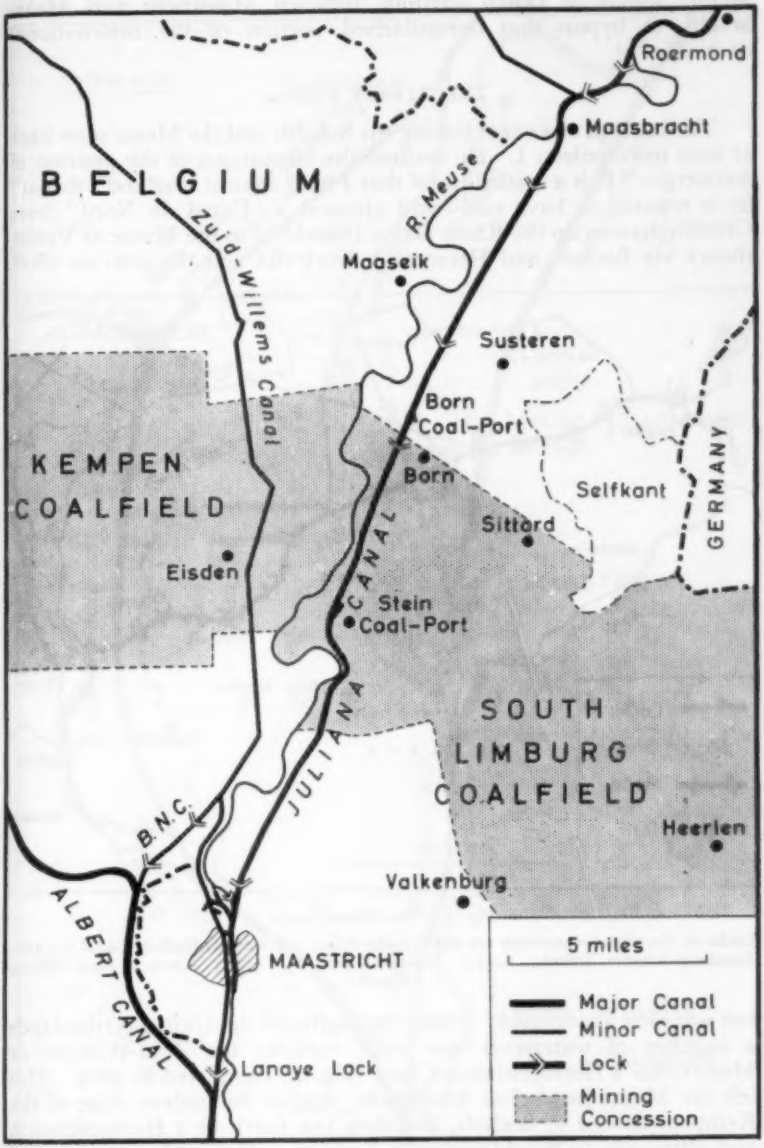


Fig. 1. The Juliana Canal.

The area of the Selfkant is shown, acquired by the Netherlands from Germany on 23rd April 1949 as part of the post-war settlement. B.N.C. : Briegden-Neerharen Branch Canal.

Meuse, wholly in Dutch territory, between Maastricht and Maasbracht, to bypass that unregularised portion of the international river (Fig. 3).

The Albert Canal

The concept of a canal linking the Scheldt and the Meuse goes back at least to Napoleon I. He realised the advantages of the position of Antwerp—" It is a loaded pistol that I hold against England's throat" he is reputed to have said—and planned a ' Canal du Nord ' from Grimlinghausen on the Rhine above Düsseldorf to the Meuse at Venlo, thence via Bocholt and Herentals ; work did actually start in 1808,

Fig. 2. The Albert Canal.

Locks on the minor waterways are not shown. H.B.C. : Herentals-Bocholt Canal ; T.S.C. : Turnhout-Schoten Canal ; D.T.C ; Dessehel-Turnhout Canal ; Z.W.C. : Zuid-Willems Canal.

but was soon abandoned. Under the régime of the United Netherlands a number of waterways was built, notably the Zuid-Willems or Maastricht-'s Hertogenbosch Canal (Fig. 2), completed in 1826. This left the Meuse just below Maastricht, skirted the eastern edge of the Kempen plateau to Bocholt, and then ran north to 's Hertogenbosch and ultimately to the Meuse near Engelen. The final recognition of Belgian independence in 1839 divided this canal into three parts : a short Dutch portion within the Maastricht area, a Belgian section from Smeermaas to the frontier near Bocholt, and a northerly Dutch portion. In 1844 Belgium took advantage of her section of the Zuid-Willems

Fig. 3. The Albert Canal and the Maastricht territory.
Based on various large-scale Belgian and Dutch official maps and plans.

Canal and began to construct from this waterway at Bocholt a new canal, known as the Meuse-Scheldt Junction or Kempen Canal, which took fifteen years to complete. Until the ultimate construction of the Albert Canal, this was the only water-route from Liège to Antwerp, yet by this canal the most rapid voyages between the two cities took forty-three hours for a motor-barge and seventy-seven hours for a tow of four dumb-barges. There were several other serious disabilities : ten locks and numerous swing- and lift-bridges had to be negotiated ; the minimum depth was only about seven feet and therefore the maximum barge capacity was limited to six hundred tons ; and vessels were obliged to pass through Dutch territory in the Maastricht area on their way to Liège. When the Albert Canal was constructed it incorporated some enlarged sections of this Junction Canal, and the remaining portion was renamed the Herentals-Bocholt Canal. In spite of the disadvantages, both the last canal and the Zuid-Willems were and still are extensively used, for together with a number of loops and branches they serve many of the villages and towns of the northern and eastern Kempenland.

Nevertheless, even before the war of 1914-18 there had developed a growing sense of the inadequacy of these canals, and a preoccupation with the problem of creating a new major waterway across north-east Belgium. This would not only form a direct all-Belgian route between Antwerp and Liège, but it would provide the necessary cheap transport for the increasing output of the new Kempenland coalfield, the existence of which had been proved in 1901 when the first coal was raised to the surface. Various companies interested in the coalfield considered that the construction of a *Canal Charbonnier* across the district would prove to be a most important factor in its development. It was argued, too, that it would have a definite strategic value as a defence line across the north-east of the country, in effect duplicating the obstacle of the Meuse. Various projects were put forward in the years following the war of 1914-18, but after lengthy deliberations by the government-appointed *Commission Bouckaert* a route from Hasselt via Eigenbilzen to the Meuse valley at Visé was finally adopted.

The Netherlands Government objected to the scheme, on the grounds that it was an infringement of international law. At the Congress of Vienna in 1815 the Meuse, together with the Scheldt, Rhine and other rivers, had been given the status of international rivers and placed under the jurisdiction of a Committee of Navigation appointed by the Congress. Between 1833 and 1885 there were no less than sixteen international treaties and conventions concerned with the navigation of the Meuse. The most important of these was the Treaty of The Hague, the outcome of Belgium's construction of the Meuse-Scheldt Junction Canal, for the Netherlands claimed that this canal effected a withdrawal of water from Meuse to Scheldt. The Treaty therefore defined the precise volume of water which might be withdrawn from the Meuse through a single feeder-canal near Maastricht, to supply both the Zuid-Willems Canal and the Meuse-Scheldt Junction Canal which connects with it near Bocholt. This agreement, modified by some technical formulae included in a supplement signed at Brussels

in 1873, has remained in force. At the Treaty of Versailles, the international character of the Meuse was reiterated, but in general terms.

So when the Albert Canal scheme was adopted by the Belgian government, the Netherlands objected, under the 1863 and 1873 agreements, on the grounds that large-scale withdrawal of water from the Meuse was involved, since there is a fall of 184 feet between Liège and Antwerp. The Belgian defence was that the maximum amount of water to be withdrawn would not exceed five cubic metres per second, causing no impediment to Meuse navigation, and further they claimed that the new barrages under construction above Liège would more than compensate for this withdrawal by maintaining a regular depth of water in the river.

The Netherlands government finally took the whole question in 1936 to the Permanent Court of International Justice at The Hague. Ultimately the Belgian plans for the construction of the Albert Canal and the consequent minor diversion of Meuse water were sanctioned. The Netherlands then requested that Belgium should be responsible for the construction of a new lock near Lanaye, which would form a through-link between the Albert Canal and the surviving Dutch portion of the old Liège-Maastricht Canal. The present old lock can accommodate only 600-ton barges, but the new one would enable barges of 1,000 tons and above to pass from Liège to Maastricht, thence along the Juliana Canal and so to the lower Meuse. This the Belgians were at first unwilling to accede, since such a through-route of Liège-Maastricht-Rotterdam was in fact the very feature which the Albert Canal was intended to obviate. As 3·6 million tons of freight passed through this lock in 1954, the points of view of both countries can be appreciated. Belgium however finally agreed to enlarge the Lanaye lock.[2] So the construction of the Albert Canal proceeded.

The Albert Canal, eighty miles in length (Fig. 2), proved to be an immense undertaking which took ten years to complete. Ironically, and bitterly, it was finally officially opened during the German occupation on Christmas Day, 1940, for the intended opening during the International Water Exhibition at Liège in July, 1939, had been postponed owing to a disastrous breach in the embankments near Hasselt.

The canal takes off from the Meuse below Monsin Island, using the course of the old Liège-Maastricht Canal, built in 1850, which ran parallel to and on the west side of the Meuse, as far north as the old Lanaye lock. This section of the canal was enlarged to the overall dimensions of the new waterway. The major physical obstacle then encountered was the upland ' neck ' linking the Kempen and Hesbaye plateaus, which the canal had to pierce in order to circumvent the western boundary of the Maastricht area. A series of enormous cuttings was made (Fig. 3) ; the ' Tranchée de Caster ' was excavated through the St. Pietersberg ridge, followed by the Vroenhoven-Veldwezelt cuttings, which are nearly six miles long, some 200 yards wide, and in places over 200 feet below the surface of the plateau. The vast quantities of excavated earth were removed to other sections further west to build the embankments. From Briegden to Genk the Eigenbilzen cutting was

made through a series of low hills and then the canal was continued westwards along the Demer 'furrow' into the Scheldt lowlands. For some thirty miles it makes use of enlarged sections of the old Meuse-Scheldt Junction Canal and its Hasselt Branch, and for most of this 'lowland course' it is contained within immense embankments, 200 yards or more in width at their base. Finally, the canal enters the port of Antwerp by way of the Strasbourg and Lefebvre Docks.

The fall of 184 feet between Liège and Antwerp is negotiated by six groups of locks, the locations of which are shown on Figure 2; a seventh lock at Monsin is used to keep the level of the Meuse at Liège stable at about 200 feet above sea-level, and is normally left open. Each group of locks is triple; the two largest can accommodate 2,000-ton Rhine barges, the third 600-ton barges, and three vessels can be locked through simultaneously. Sixty-five bridges were constructed, all of which (with one exception) were destroyed during the war of 1940-45, but subsequently have been rebuilt. Canal ports have been developed, apart from the important terminals at Liège and Antwerp, notably the coal-ports at Genk, Zolder and Beringen, and the port of Hasselt, while there are numerous smaller ports and factory quays serving the Kempen industrial region.

The construction of the Albert Canal made possible another important contribution to the pattern of the Belgian waterways. A short link-canal, three miles in length, known as the Briegden-Neerharen Branch, was constructed in 1935 around the north-western sector of the perimeter of the Maastricht district (Fig. 3). It connects the Zuid-Willems Canal near Smeermaas, before it enters the Netherlands from the north, with the Briegden Basin on the Albert Canal, so providing a continuous all-Belgian water-route along the eastern edge of the country.

The Albert Canal serves primarily as a through-route between Antwerp and Liège, and its importance is shown by the fact that in 1954 there were no less than 64,766 separate journeys of laden barges, apart from nearly 35,000 return journeys of barges in ballast. In all, 21·2 million tons of freight were transported. If this figure is broken down, the results are as follows:

	(*million tons*)
Internal freight (i.e. within Belgium)	12·1
Exported freight	4·3
Imported freight	4·0
In transit through Belgium from one country to another	0·8
Total	21·2

This is strikingly indicative of the importance of the canal both within Belgium and for foreign trade; three-sevenths of the freight carried concerned other countries.

If we seek to compare this activity with other Belgian waterways, the most useful indication is in terms of 'ton-kilometres', a figure which is the product of the load in tons and the distance in kilometres that it is carried. This gives a more accurate impression of the activity on

various waterways than does absolute tonnage of freight, as it differentiates between long- and short-distance loads. The figure for the Albert Canal in 1954 was 1,160 million ton-kilometres, that for all Belgium 4,116 ; thus the Albert Canal accounted for more than a quarter of the national aggregate. Furthermore, it is possible to calculate a value of ' ton-kilometres per kilometre ', that is, a division of the total number of ton-kilometres by the length of the waterway in kilometres, thus obtaining a strictly comparable representation of the respective importance of each. On this basis, the figure for the Albert Canal in 1954 was 8·92, the figure for all Belgium 2·62 million ton-kilometres per kilometre.

One of the main arguments for the construction of the canal was that it would skirt the southern edge of the Kempen coalfield, and thus provide a convenient outlet for it. This field, worked by seven large-scale collieries, produced in 1955 about one-third of the total Belgian output of almost thirty million tons. The Albert Canal, serving six of the collieries, conveyed about four million tons.[3] Three coal-ports were specifically constructed to handle Kempen coal. The port of Genk, managed by the *Société du Port Charbonnier de Genck S.A.*, was developed jointly by the Winterslag, Zwartberg and Waterschei companies, with which it is linked by rail, and is used also by the Houthalen colliery. Kempen coal can be shipped from the Genk coal-port to Liège in about seven hours and to Antwerp in nine or ten hours ; it is interesting to note that about two-thirds of the coal loaded moves towards Liège, the rest towards Antwerp. The Zolder and Beringen ports were developed further west along the canal to serve the Helchteren-Zolder and Beringen-Koersel collieries respectively.

Coal is the dominating commodity transported, but not the only one, as shown by the following analysis of loadings and unloadings along the Albert Canal in 1954 :

LOADINGS AND UNLOADINGS AT ALBERT CANAL PORTS, 1954

(*thousand tons*)

	Loadings	Unloadings
Coal	4,111	404
Building materials, timber, glass	597	448
Quarried products	417	1,512
Chemical products	302	467
Agricultural products	62	601
Minerals	50	82
Metallurgical products	76	26
Oil	11	71
Others	88	72
Total	5,714	3,683

These figures indicate the importance of the canal to southern Kempen towns such as Hasselt, Kwaadmechelen and Herentals, to the chemical, metallurgical and glass works in the Kempen industrial area itself, and to the quarries, cement-works and brick-works sited along the Albert Canal, the other Kempen canals and the Meuse valley.

The Juliana Canal

The Juliana Canal, completed in 1936, leaves the Meuse at Limmel in the northern suburbs of Maastricht, within which the river is canalized and lined with quays (Fig. 3). The river ceases to be navigable at the point where the canal takes off at the Bosscherveld barrage, designed to keep the Meuse depth uniform within the port of Maastricht. The Juliana is twenty-one miles in length, and the fall in level of forty-five feet is accommodated by four locks at Limmel, Roosteren, Born and Maasbracht. The canal has an overall width at the water-level of 152 feet, with a bottom width of just over fifty feet and a depth of 16·5 feet ; it can accommodate 2,000-ton barges. Apart from the river-port of Maastricht and two basins opening off the canal at Maasbracht, two ports were constructed to serve the South Limburg Coalfield, the Stein port owned and operated by the *Staatsmijnen in Limburg* (Pl. 3), and the Born port which handles coal from the Limburg collieries operated by several private companies.

The waterborne freight of the Netherlands is measured and returned in terms of cargo passing recording points at a number of important locks and junctions. The 1954 figures for the Juliana Canal, recorded at the lock above Maasbracht, totalled about 10·4 million tons.

One function of the canal was to serve the South Limburg coalfield, and the two coal-ports of Stein and Born were constructed to handle coal from the State mines and the private mines respectively. Stein has a capacity of four and a half million tons, Born of two million tons, and both are equipped with modern coal-handling facilities. It is interesting to note however that neither port has regained its pre-war importance and each is operating considerably below capacity at the present time.

In 1954 the coalfield produced 12·1 million tons, of which rather less than half was consumed within the South Limburg industrial region itself. Some coal went to the glass, pottery and cement works of the Maastricht area, and much was consumed at or near the collieries in the coke-ovens, power-stations and by-products chemical plant. In point of fact nearly half of that which was despatched from the province went by rail. The reason for this is that the Mines Railways Department owns its private standard-gauge system, with its headquarters at Heerlen, and this system is linked to the sidings at each colliery, to the extensive marshalling yards at Susteren in the north, and so to the State Railway. Nevertheless, the Juliana Canal did handle 3·7 million tons of coal. Most of this (3·06 million tons) moved northwards, virtually all of which came from the Limburg field, a small amount from southern Belgium. But it is interesting to note that 669,000 tons moved southwards through the Maasbracht lock at the northern end of the canal; this was not Limburg coal, of course, but Ruhr coking coal on its way to southern Belgium.

Other commodities transported along the waterway included 4·3 million tons of building materials (more in fact than the coal freightage, but much of it consisted of cheap and bulky sands, gravel and building-

stone), as well as nearly a million tons of cement, mortar and lime. Over 800,000 tons of fertiliser, the output of the various colliery by-product plants, were also shipped by canal.

About two-thirds of the total freight moved northwards into the main part of the Netherlands. Yet the southern movement of 3·3 million tons is quite impressive, since this was intended either for the Maastricht area or for destinations further south in Belgium. In fact, rather more than half of this (1·7 million tons) passed on through Maastricht, along the surviving Dutch portion of the Maastricht-Liège Canal, and so through the Lanaye lock on to the Albert Canal. Most of this traffic originated in the Netherlands, but some 700,000 tons came from Germany. Moreover, a further 1·8 million tons of freight moved northwards through the Lanaye lock, about a third of which consisted of metallurgical products. There is then the quantitative indication of an important through-route by way of the Juliana, the Maastricht-Liège and the Albert Canals, for about 3·6 million tons of freight passed in 1954 through the Lanaye lock, the link between the Belgian and Dutch systems. This emphasizes the importance which the Dutch attach to the enlargement of the lock already discussed.

It has already been stressed that the Juliana Canal is of value not merely to the Netherlands. This is reiterated by the fact that of all traffic along the canal, averaged over the past few years, Dutch barges provided 51 per cent of the capacity, Belgian about 25 per cent, German 13 per cent and French 6 per cent.

Summary

The Albert and Juliana Canals clearly make an important contribution to the waterway pattern of Belgium and the Netherlands and therefore to that of western Europe, the former linking the Scheldt and the Meuse, the latter by-passing the one unnavigable section of the Meuse. It is not easy to compare the freight statistics for the two waterways, since the method of recording is not strictly comparable. However, the Albert Canal transported about twenty-one million tons of freight in 1954, the Juliana Canal about ten million tons, which gives a broad indication of the relative order of magnitude involved. This naturally would be expected, as the former is nearly four times as long as the latter and virtually crosses Belgium from her greatest port to her chief industrial area, serving numerous towns and a dense population. The latter is situated in a remote part of its country, a lateral canal along a river valley.

Nevertheless, in two outstanding respects their functions are comparable. In the first place, each is a link designed to bring the respective southern industrial area within the hinterland of a great port—the Albert Canal for Antwerp, the Juliana Canal for Rotterdam. In the second place, a major factor which stimulated the construction of each was the need to serve a coalfield; in 1954 the Albert Canal carried 4·1 million tons of coal, the Juliana not appreciably less with 3·7 million tons.

Today, with the close associations involved in the Benelux Union

and in the two countries' membership of the European Coal and Steel Community, much of the rivalry involved in the past between Antwerp and Rotterdam has disappeared. Agreements about the respective hinterlands, about Rhine traffic, about freight-rates, have gradually been formulated. The Albert and Juliana canals are not merely national but international waterways, as their freight statistics have shown, and in the pattern of a western Europe more closely united through both economic and strategic considerations both have an essential rôle.

[1] The word Meuse is used in this text for the River generally, although the official Dutch form is Maas.

[2] The Lanaye lock had not been enlarged by 1956, although "forthcoming negotiations between both countries are expected to result in the construction of a new lock . . . enabling barges up to 2,000 tons to sail from the Albert Canal and the Juliana Canal v.v." (letter from the *Ministerie van Verkeer en Waterstaat* to the writer, 13th March 1956).

[3] The Eisden colliery, in the east of the field, has its coal-port on the banks of the Zuid-Willems Canal.

Detailed statistics of the Belgian waterways are contained in the *Annuaire Statistique de Belgique* (Gand). As there is some inevitable time-lag in this publication, the same information is published earlier in the monthly *Bulletin de Statistique* for the June following the year in question, and is reprinted separately as *Statistique de la Navigation Intérieure*. These figures are collated and published by the *Institut National de Statistique* of the *Ministère des Affaires Economiques*.

Unpublished Belgian statistical material was furnished by (i) the *Bureau de Renseignements et de Documentation* of the *Institut National de Statistique* in Brussels, from the *Direction générale des Voies navigables* of the *Ministère des Communications*; and (ii) the *Société du Port Charbonnier de Genck S.A.*

Statistics of the Netherlands' waterways are summarized annually in *Jaarcijfers voor Nederland*. More detailed information is contained in (i) *Statistiek van de Scheepvaartbeweging, telling van het verkeer aan sizenlu en bruggen*; (ii) *Statistiek van het Binnenlandse Goederenvervoer te Water*; and (iii) *Statistiek van de Internationale Binnenvaart*. These are all compiled by the official Central Bureau of Statistics, from information supplied by the *Ministerie van Verkeer en Waterstaat, Directoraat-Generaal van Scheepvaart*.

Unpublished statistical and other information was supplied by (i) Dr J. Idenburg, of the Netherlands Central Bureau of Statistics at The Hague; (ii) Mr P. J. A. Frische, of the *Voorlichtingsdienst van de Nederlandsche Steenkolenmijnen* (relating to coal-traffic on the Juliana Canal); and (iii) Mr W. R. van der Ben, of the *Directoraat-Generaal van Scheepvaart* of the *Ministerie van Verkeer en Waterstaat*.

A full account of the construction of the Albert Canal is given by A. Delmer, *Le Canal Albert* (Liège, 1939); volume I consists of text, fully illustrated with photographs and diagrams, volume II consists of 19 folded sheets of maps, geological sections, etc.

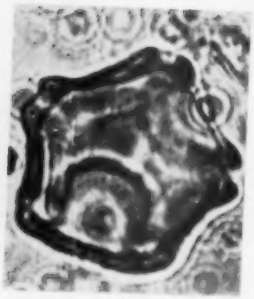
ACKNOWLEDGEMENT

The Society wishes to thank all those who have reviewed books and other publications during the period 1955-56.

Photograph published by permission of the Voorlichtingsdienst van de Nederlandsche Steenkolenmijnen

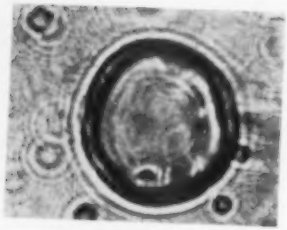
PL. 3. THE STEIN COAL-PORT AND THE JULIANA CANAL

Showing detachable coal trucks being unloaded direct by crane into adjacent barges.



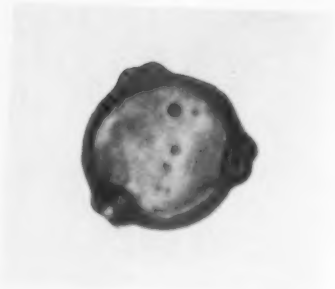
Alder (*Alnus*)
× 1000

Heather (*Calluna vulgaris*)
× 1000



Grass (*Graminaceae*)
× 750 approx.

Pine (*Pinus*)
× 700



Birch (*Betula*)
× 900

Elm (*Ulmus*)
× 900

Pl. 4. PHOTOMICROGRAPHS OF POLLEN GRAINS

Characteristics of form by which certain species are identified : Alder—five pores, penetrating outer wall, linked by internal bands : Heather—tetrad formation : Grass—round smooth wall with one pore : Pine—two air-sacs : Birch—smooth rounded wall with three protruding pores : Elm—five pores and surface sculpturing.

POLLEN ANALYSIS OF PEAT DEPOSITS IN SCOTLAND

S. E. Durno

Of the millions of pollen grains liberated each year by different plants only a small fraction fulfils the natural function of fertilisation. Most falls as ' pollen rain ' on the land or water surfaces in the vicinity of the parent plants. While much of this is completely destroyed a certain percentage may be trapped and preserved in underwater sediments or in peat bogs where anaerobic conditions slow down the process of decomposition. The durability of the outer wall of each pollen grain allows its preservation intact in such deposits for thousands of years, while characteristics of form, size and detail of the surface structure of each grain make possible, under the microscope, the identification of the particular family, genus, or even species of the plant from which it originated (Pl. 4). The analysis of the pollen preserved in such deposits allows not only the identification of the various plants which contributed to the ' pollen rain ', but the proportion in which they did so over that period during which the sediments or deposits accumulated. Peat deposits, particularly, preserve in the form of pollen a long and continuous record of the vegetation which grew in the immediate neighbourhood. Indeed in them it is possible to trace the history of our flora back to the end of the Quaternary glaciation.

Pollen analysis is a relatively modern technique still in its developmental stage, but already results obtained from its application have proved of considerable value in the related fields of Geology, Climatology, Plant Ecology and Archaeology : during the past few decades it has been widely used in North West Europe and North America to advance the study of Quaternary deposits and as a basis for the chronology of the later part of this period. Much of the early work was done in Scandinavia, where the principles of the method were first expounded and its practice pioneered by the Swedish geologist Lennart von Post. In the British Isles a considerable amount of valuable research on this subject has been undertaken, particularly by Godwin and his colleagues of Cambridge and Mitchell of Dublin. Of the data published, however, very little comes from Scottish sources. This is a fact which is surprising in view of the abundance of peat deposits and is to be regretted in the light of the many still unsolved glaciological and ecological problems in this country. Only papers by Erdtman, Blackburn, and Fraser and Godwin deal with pollen analysis of Scottish peats. The first consists mainly of a series of arboreal pollen diagrams which the author Professor G. Erdtman of the University of Stockholm, prepared as the result of a month spent sampling peat deposits in the Highlands and Islands in 1922. This was valuable pioneer research, but it is natural that the work bears the stamp of the period in which it was carried out when the modern type of diagram with a system of chronologically

arranged zones had not been devised. Within the last decade pollen analyses by Miss K. Blackburn of Durham University and a joint paper by the late Dr G. K. Fraser of the Macaulay Institute, Aberdeen, and Dr H. Godwin of Cambridge University, have been published. These papers deal respectively with a peat deposit on the Island of Barra and two raised mosses in Lanarkshire and Aberdeenshire : they are more detailed than Erdtman's analyses and are tentatively zoned according to the Godwin system.

The purpose of this paper is to present the results of recent pollen analyses of peat from five areas of raised bog in Scotland and to attempt to correlate the data with that from the rest of the British Isles.

The following table summarises the location and site of the five deposits analysed :

Name of peat mosses	Altitude		Depth of Peat		Location and National Grid Reference
	Feet	Metres	Feet	Cms	
1. St Fergus Moss .	150	45	23·6	720	N.E. Aberdeenshire NK 055535
2. Netherley Moss .	400	120	21·6	660	Between Dee valley and coast N.E. Kincardineshire NO 860940
3. Flanders East Moss.	50	15	23·3	710	Upper Forth valley South Perthshire NS 630980
4. Darnrig Moss .	610	185	32·1	980	Stirlingshire NT 880755
5. Airds Moss . .	750	230	24·6	750	Uplands of central Ayrshire NS 610250

Sites must be chosen with care and before taking samples for analysis it is essential to study thoroughly the location of the deposit in relation to surrounding topography, drainage, vegetation, etc. The five peat mosses which provide material for the present investigation are all of the raised moss, basin peat type, *i.e.* they represent the ultimate stage of peat development which started from the overgrowing of a pond or marsh.

Site 1. ST FERGUS Moss is the remains of a larger deposit and lies in a rather poorly defined depression in the undulating Buchan plain.

Site 2. NETHERLEY Moss is a well-defined basin lying among the low foothills at the eastern extremity of the Kincardineshire Grampians.

Site 3. FLANDERS EAST Moss lies in a trough on the interfleuve between the River Forth and its tributary the Goodie Water.

Site 4. DARNRIG Moss is one of a number of deep peat-filled hollows which lie on the Slamannan plateau.

Site 5. AIRDS Moss, situated on an interfluvial ridge between the river Ayr and its tributary the Bellow Water, has not such a well-defined ' basin ' form as the other four sites.

A series of boring is necessary to ascertain depths and to reveal stratifications. Such preliminary work enables a diagram of a vertical section to be drawn showing variations in the type and composition of the peat with increase of depth (Fig. 1). From such a section the best point at which to take samples can be decided. In the analyses presented here samples were obtained at intervals of 10 or 5 cms in depth, using a borer of the Hiller type—a tool designed to bring up, in a closed chamber, material from any required depth.

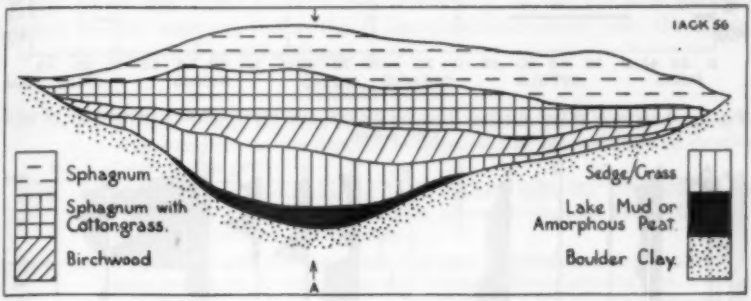


Fig. 1. Vertical section through a peat moss.

Preparations for pollen counting were made by a modification of the Erdtman method. In the laboratory samples were subjected to chemical and physical treatment designed to remove or destroy as much as possible of the material in which the pollen was embedded. Microscopic investigation usually reveals that nearly all the pollen has been contributed by a comparatively small number of species of which trees form a very important group. Compared with herbaceous plants, trees produce great quantities of pollen, and as this country, until fairly recent times, was heavily wooded, data is controlled to a great extent by arboreal pollen.

In analysing and counting the general practice of basing calculations on 150 tree pollen grains (excluding hazel) was followed. By this means 150 grains from arboreal species are counted from each sample before expressing the number of all pollen grains as a percentage of that figure. By the time the requisite number of tree pollen grains has been counted for any one sample hundreds—or perhaps only a few—non-arboreal representatives may be recorded dependent upon whether the sample is representative of a period of heavy forest cover or one of recession or clearance of trees.

By means of a pollen spectrum the proportion of pollen of various species in each sample analysed can be illustrated. A series of such spectra, at intervals from the top to the bottom of the deposit, may be drawn as a series of bar graphs (Fig. 2) or in the form of a continuous

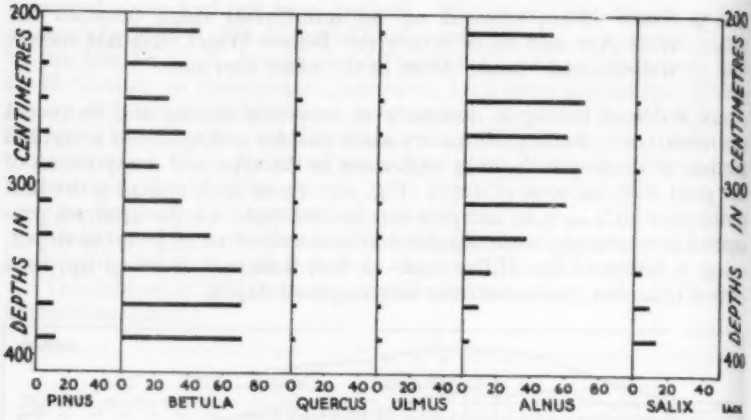


Fig. 2. A series of pollen spectra, from 2-4 metres. and expressed as a percentage of total tree pollen.

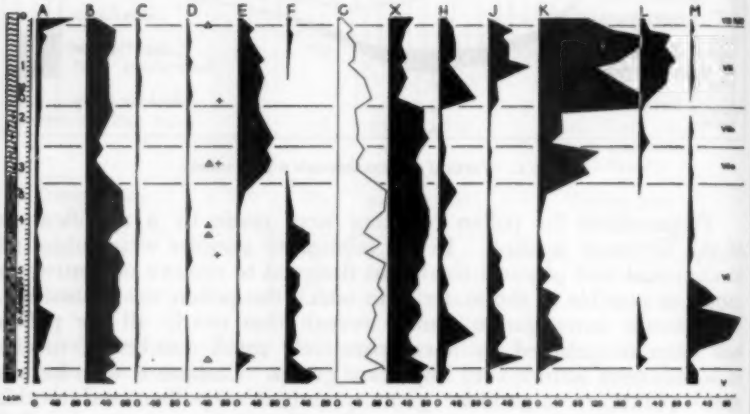


Fig. 3a. St. Fergus Moss.

Figs. 3a-e. Pollen diagrams of five Scottish peat mosses (the following key applies to all five figures).

TYPE OF PEAT : 1. mineral subsoil : 2. sedge/grass : 3. wood (mainly birch) : 4. heather (*Calluna vulgaris*) : 5. cotton grass (*Eriophorum vaginatum*) : 6. bog moss (*Sphagnum spp.*)—humification high : 7. bog moss—humification low.

TYPES OF POLLEN expressed as a percentage of total tree pollen.

Arboreal species : A. pine (*Pinus*) : B. birch (*Betula*) : C. oak (*Quercus*) : D. elm (*Ulmus*) : E. alder (*Alnus*) : F. willow (*Salix*) : G. hazel (*Corylus*).

Non-arboreal species : H. grass (*Gramineae*) : J. sedges (*Cyperaceae*) : K. heaths (*Ericaceae*) : L. bog moss (*Sphagnales*) : M. ferns (*Filicales*).

X. Total tree pollen expressed as a percentage of total pollen.

Δ—ash (*Fraxinus*) . + —lime (*Tilia*) : □—beech (*Fagus*).

Horizontal lines represent the limits of the pollen zones vi-viii.

profile: the latter pollen diagram (Fig. 3a), now the accepted way of presenting the summation and to a certain extent the interpretation of the data, has been used in all cases for the analysis of results here.

If the frequency curves of the various species are examined certain striking changes are apparent. These fluctuations which are common to all pollen diagrams from North and West Europe, have made it possible to devise a system of zones into which, in a general way, all diagrams can be divided. These zones (numbered in chronological order I to VIII) are based on periods of relatively constant vegetation and are believed to be substantially contemporaneous at various sites: and changes from one zone to another have been regarded as indicative of climatic change. The zonation of the diagrams presented here (Fig. 3a-e) has been worked out according to the criteria used by other British workers, but as this is not possible in every case the zoning must be regarded as provisional only.

POLLEN ZONES

ZONES I-IV of other British deposits are not represented at all in the accompanying diagrams because the deposits in question had not commenced development at this period.

ZONE V: Tree pollen is dominated by birch (*Betula*) with the other tree species represented by small but variable amounts—though hazel (*Corylus*) is tending to increase in frequency.

ZONE VI commences with the rise of hazel to very high values; this usually coincides with a small increase in elm (*Ulmus*). Birch remains high throughout the zone, while hazel may also continue high or drop very considerably before the end. The rise and rapid diminution of hazel is a phenomenon recorded constantly and, although the reason is obscure, is of great value in correlating diagrams from different sources.

Another example of a sudden change in the vegetation is seen at the boundary between Zones VI and VII.

ZONE VII: SUB-ZONE (A). At the transition alder (*Alnus*) rises rapidly accompanied by a concurrent lowering of birch and to a lesser extent of pine (*Pinus*): and this zone extends to a point where the elm curve falls by a small but quite appreciable amount. This change indicates a transition from a cool dry Boreal or continental type of climate to a cool wet Atlantic or oceanic one. It has also been suggested that this Boreal-Atlantic Transition, as it is called, marks the final severing of Britain from the continent by the joining of the English Channel to the North Sea across the Straits of Dover.

SUB-ZONE (B) is not easy to delimit, but the upper boundary may be placed at the level where the total tree pollen curve starts a downward trend. This may be gradual or sharp and it may occur at or near the same level as maxima for hazel and alder.

ZONE VIII continues with birch gradually increasing and alder remaining constant or decreasing slightly. The total tree pollen curve may rise somewhat from the lower boundary of the zone or continue without much change. SUB-ZONE VIII (MODERN) may appear at the top of the profile showing sudden changes in some of the curves and in many Scottish diagrams there is a particularly striking peak for pine pollen.

The diagrams show that peat development in these mosses started at roughly the same time—in Zone V or early in Zone VI. At this time birch was the dominant tree with some pine and a sporadic occurrence of alder. In Zone VI the onset is indicated by the great

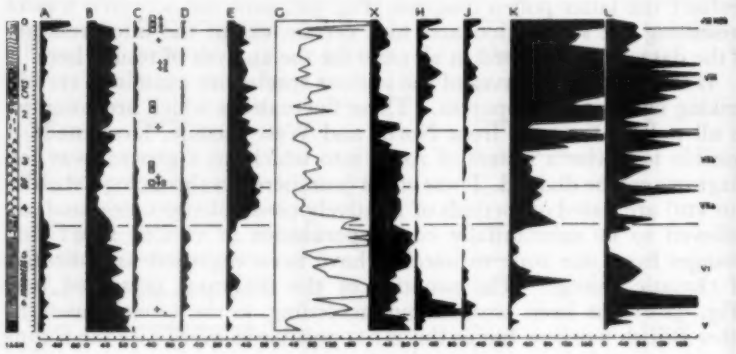


Fig. 3b. Netherley Moss.

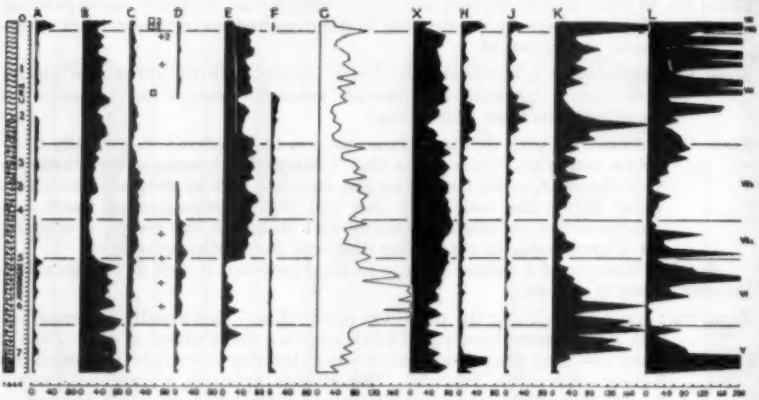


Fig. 3c. Flanders East Moss.

increase in hazel; oak and elm increase their representation to some extent but not to a degree comparable with that generally found in diagrams from England and Wales. Pine also may increase a little, but birch still remains the dominant tree species. The close of Zone VI, which also marks the end of the Boreal Period, is clearly seen in all the diagrams where alder rapidly increases and birch decreases. At this level the pine curve may also show a marked decrease, but occasionally—as in Darnrig (Fig. 3d)—this is not discernible.

From this level—the Boreal-Atlantic Transition—certain long-term trends are seen. Birch, which indeed never falls to low values, gradually increases and together with alder shares the dominance of the diagrams until modern times. Oak and elm which are represented by appreciable amounts of pollen remain subsidiary species. The elm recession, however, marking the end of Sub-zone VIIA is obvious and

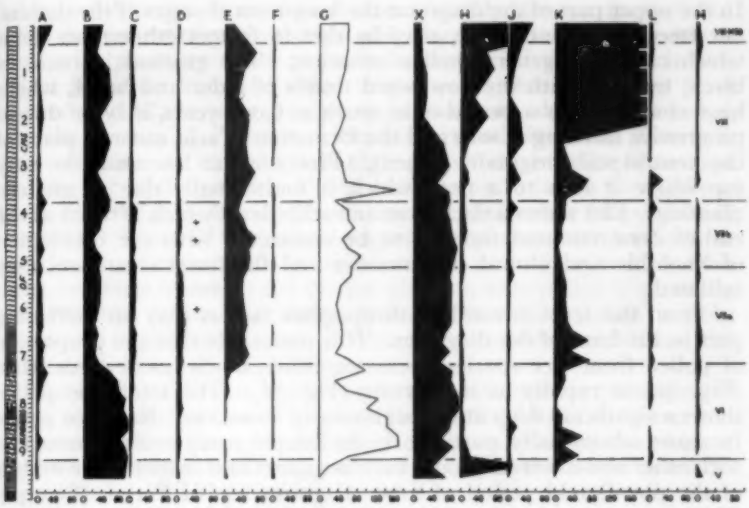


Fig. 3d. Darnrig Moss.

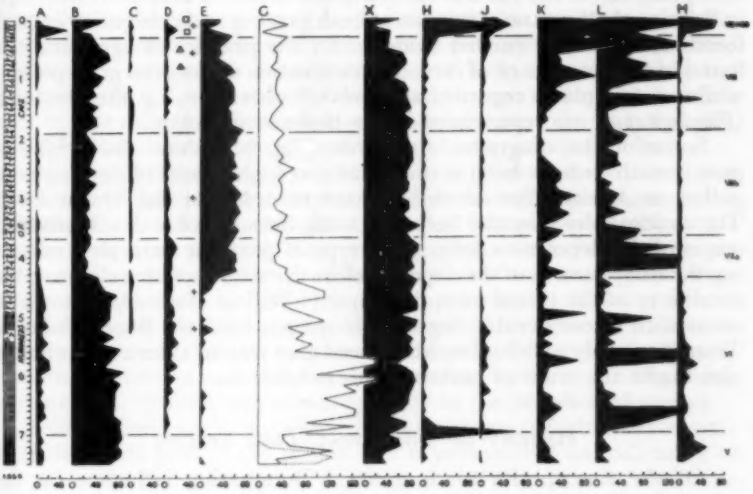


Fig. 3e. Airds Moss.
dotted line—*Myriophyllum alterniflorum*.

is the last of the generally accepted features which are used to delimit the pollen zones in British profiles.

Since this time it appears that the efforts of early man to control his environment were taking effect on the trees and other vegetation.

In the upper part of the diagrams the long-term changes of the dominant trees, birch and alder, may be due to factors other than those which cause the general pollen zonation. The gradual increase in birch, together with the downward trends of alder and hazel, which have continued for a period of as much as 6,000 years, may be due to progressive leaching of soils and the formation of acid moor in place of the neutral soils originally present. Pine remains low until the very top where it rises to a peak which is undoubtedly due to modern planting. Elm shows a decline at an earlier level which is taken as the end of Zone VIIb and thought to be connected with the infiltration of Neolithic agricultural communities and the forest clearances they initiated.

From this level onwards anthropogenic factors play an increasing part in the form of the diagrams. It is noticeable that the proportion of pollen from tree species decreases either slowly, as in Airds Moss (Fig. 3e) or rapidly as in Darnrig (Fig. 3d). The total tree pollen shows a significant drop at the beginning of Zone VIII. Non-tree pollen increases substantially, particularly the Ericoid group so often associated with other non-arboreal groups such as grasses and sedges in the middle of the post-Boreal period of some diagrams, *e.g.* St Fergus (Fig. 3a). This phenomenon can be explained as due partly to climatic deterioration, but mainly to the intensification of the forest clearance which took place about 1000 B.C. at the transition from the Bronze to Iron Age in Britain. At this time expansion of both grazing and cultivation caused forest destruction. Further evidence for the practice of agriculture is found in the occurrence of cereals of cultivation among the grass pollen, whilst certain plants regarded as weeds of cultivation, *e.g.* the plantains (*Plantago spp.*) are represented in the herbaceous pollen.

Some of the diagrams, *e.g.* Airds (Fig. 3e), show the origin of peat growth to have been in open water as high counts of such aquatic pollen as *Myriophyllum alterniflorum* are recorded at the lowest level. The stratigraphy may also help in tracing the successive developmental stages of the deposit—a sedge/grass type of peat, for example, indicating the early growth of the deposit before the ombrogenous oligotrophic conditions of the raised moss developed. Willow (*Salix spp.*) may also occur with a considerable degree of frequency until the Boreal-Atlantic Transition, only to fall off suddenly and give way to alder : this change also marks the onset of ombrogenous conditions.

History of Individual Tree Species

Of the tree species birch exerts a dominating influence on the arboreal pollen diagram : it never falls to low values during the whole length of post-glacial time. In Zone VII, during the period of maximum alder development, it may fall to about 20 per cent, but otherwise is invariably the most abundant tree pollen recorded. In the earlier parts of the diagram it is possible that at least some of the pollen grains counted belong to the dwarf birch (*Betula nana*), but no differentiation has been made.

Although alder does not attain its greatest importance until after

the Boreal-Atlantic Transition it was certainly present in Scotland before that major climatic change took place. Its pollen is sometimes found with peaks up to 20 per cent in pre-Boreal times, and in this respect it differs from the usual frequency in those diagrams from England and Wales where, in many, virtually no alder occurs before Zone VII or late in Zone VI. Reaching its maximum in Zone VII, alder continues to contribute a high proportion of the pollen rain until the top of the profile. Pollen analyses by Erdtman (1924) from the Scottish Highlands and Islands, and by the author (unpublished) from Wester Ross and Sutherland suggest that pine and birch may have played an even greater role in the north and west of the country than in the lowlands where in the typical diagram pine-pollen is generally more frequent before the Boreal-Atlantic Transition, when it sinks almost to insignificance until, in Zone VIII (modern) it attains the peak ascribed to modern planting.

Hazel, like alder, is represented by considerable quantities of pollen at an earlier period than in the south of Britain, where it is very scarce before Zone VI : in others it is present before the onset of this zone, but only with very low values. The elm curve tends to rise gradually until the termination of Zone VIIa : subsequently there may be a small rise, but it never at any time accounts for more than a small proportion of the arboreal pollen. With oak (*Quercus*) it forms the bulk of the mixed oak-wood (*Quercetum Mixtum*) which, judging from the pollen statistics, can never have flourished to any great extent in Scotland. Oak is substantially lower than in diagrams from England and Wales : its curve is inconsistent and of little use in working out zonation. It is first noted in Zone VI and may rise to higher values later in that zone or in Zone VII, but in some diagrams it may diminish, become intermittent or disappear before the top of the profile.

Of the other tree species recorded, beech (*Fagus*)—once considered by many to have been introduced to Britain by the Romans—is infrequently noted and only from the post-Boreal period. In some diagrams modern planting may account for its more frequent occurrence in Zone VIII (modern). Ash (*Fraxinus*) is only represented very rarely and, like beech, mainly in the upper zones. A few grains of lime (*Tilia*) are recorded mainly from Zone VII and give an indication of the post-glacial climatic optimum which existed between the Boreal-Atlantic Transition and the deterioration that set in at the beginning of Zone VIII. Holly (*Ilex*) occurs sparsely in the post-Boreal period.

Pollen of willow is recorded with any degree of abundance only from the basal peat of the profile and is presumably an indication of the pre-ombrogenous stage of development of the deposit. Sporadic willow pollen may appear at any part of the profile, but it does not appear to have had any general influence on the forest composition or to have any significance beyond an indication of local conditions.

Non-Arboreal Groups

The three principal non-arboreal groups represented are the families Gramineae (the grasses) : Cyperaceae (the sedges) : and an

assemblage called the Ericoids, which comprise all the Ericaceae and allied plants commonly known as the heaths and heathers : among them by far the greatest pollen contributor is the common heather or ling (*Calluna vulgaris*). The trends of the non-arboreal species are, on the whole, less constant than those of the trees, and they give an indication of conditions prevailing on the moss and its immediate surroundings rather than over a wider region. There is, however, something to be learned from the non-tree diagram, especially if it is studied together with the total tree curve : the great rise of the Ericoid group in Zone VIIB or VIII coincides with the decline of the total tree curve and is probably due to the extension of heath after the destruction of forests in Neolithic times. Spores of *Sphagnum* and ferns are included in some diagrams, but we are not yet able to assess their significance nor to say if they add anything to the interpretation of the diagrams. The highly erratic curve for *Sphagnum* suggests that it is very susceptible to local changes of the bog surface.

As indicated above, the pollen analysis of Scottish peat deposits is still in its early stages and a rich field of research remains open to future investigators. To geographers interested in the evolution of landscape, both physical and cultural, it affords a vital key to ecological changes which have occurred since glacial times and an invaluable aid in the scientific reconstruction of past environments which conditioned the early settlement of human communities in this country. Until relatively modern times it would appear that the vegetational cover of the land exerted an important, if not dominant, influence over the distribution of population, and yet, to date, attempts to reconstruct the earlier patterns of forest, moor and heath amount to little more than intelligent guesswork based on the changes which have been shown to have occurred in England, Ireland and Western Europe. From the work which has already been undertaken Scottish plant history appears to offer a number of interesting and distinctive features and problems, but only a thorough survey will provide the data necessary for their explanation and solution. The Peat Ecology Section of the Macaulay Institute for Soil Research, Aberdeen, hopes to obtain pollen diagrams of various suitable sites, covering the country as widely as possible in order to exhibit the regional differentiation inherent in the ecological changes discussed above. The author would welcome the co-operation of geographers in such work, and wishes to thank Mr Anders Tomter and his staff of the Peat Section, Department of Agriculture for Scotland for their help in locating suitable sites for sampling.

The Editor is pleased to announce that Mr Durno hopes to let readers of S.G.M. know from time to time how such work in Scotland is progressing.

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INTERNATIONAL GEOGRAPHICAL CONGRESS

1956

The most representative gathering of geographers since the war met at Rio de Janeiro in August for the Eighteenth International Geographical Congress and the Ninth General Assembly of the International Geographical Union. Large European delegations, including those from the U.S.S.R. and Eastern Europe, together with strong support from Asia and the Americas, with African, Australian, and New Zealand members, ensured that all types of geographers and geography were represented. The President of Brazil and the Brazilian Foreign Minister graced the proceedings, and Professor Stamp, the president of the International Geographical Union, gave a forceful opening address on geography and the problems of world population.

Most of the delegates were housed in dormitories in the Naval Academy which, set out on a promontory in Guanaraba Bay, had a fine prospect of the truly spectacular skyline of Rio. Here the regular sessions of the Congress were held from the 9th to the 18th of August. Special evening sessions in the Ministry of Education, at which outstanding Brazilian experts spoke, were organised on aspects of the life and geography of Brazil. A magnificent reception was given by the municipal authorities at the yacht club, and three or four excursions were run in and around Rio. There were also very fine exhibitions of maps and atlases, both by member countries and also by Brazilian agencies.

Meetings occurred concurrently in thirteen sections of the Congress, twelve commissions of the I.G.U., and two special symposiums respectively. The sections consisted of cartography and photogeography; geomorphology; climatology; hydrography; biogeography; general human geography; the geography of population and settlement; medical geography; agricultural geography; the geography of industry, transportation and trade; historical and political geography; methodology; regional geography. As co-chairman of the section on cartography the writer was impressed by the progress made, both in thought and technique, since the last congress. Projects then adumbrated had come into being; new methods and new instruments had been used and tested. The application of photogrammetry and photo-interpretation to mapping, often in place of ground survey procedures, was striking. In the sections on physical and economic geography more quantitative methods were put forward to assist in the more exact measurement of geographic

relationships. In fact, in many papers authors called for a more quantitative approach to geography, although discussion revealed a no less earnest belief in the qualitative approach. The wide range of papers was stimulating in the extreme, and seemed to indicate that geography was still far from finding its frontiers.

The commissions were in the main studying specific problems deemed to be of peculiar relevance or urgency. There was a number devoted to what might be termed the purely scientific aspects of geography—the evolution of slopes, the correlation of erosion surfaces on the coasts of the Atlantic, karstic phenomena, coastal sedimentation, and periglacial morphology. Another group considered the bibliography of ancient maps, the bibliographical classification of geographical publications, and the teaching of geography. Still a third group of commissions applied themselves to world problems with which geography was concerned. These addressed themselves to the questions of health and disease, world resources and land use, and the use of marginal lands with special reference to the arid zones. Particular enthusiasm was shown for the survey of underdeveloped or undeveloped areas, where the geographer's contribution was deemed to be considerable.

Both prior to and after the conference extended field trips were organised to enable delegates to discover and become familiar with the major regions of Brazil. Studies were made of primitive communities in Amazonia, of ranching estates and mining camps in the interior plateau, of the intensive agriculture of the coastal or near-coastal areas, and also of the industrial and urban expansion so noticeable in the south of Brazil. Thus geographers were able to see the development of the tropics at various levels of technology and under different social circumstances. Altogether the conference and the related excursions were considered to be an outstanding success. Much of this success was undoubtedly due to the Brazilian organising committee under Professor Sternberg, to whom the members owe a real debt of gratitude.

J. W. WATSON.

GEOGRAPHY AT THE BRITISH ASSOCIATION 1956

The annual meeting of the British Association was held for the third time in Sheffield. This being the Association's first visit to the city since 1910 local interest was keen and contributed to an attendance of well over 150 members at the opening sessions of Section E. The leading theme of the meeting was climatology in the service of man, a topic which attracted many members from other sections. Papers on all topics reached a high standard and most of them were presented in a palatable form befitting the occasion.

In his presidential address on 'The use and misuse of climatic resources' Professor A. Austin Miller pointed out that civilised societies, with all their scientific and technological equipment, were far more wasteful of heat and water resources than most primitive peoples. The climatologist could point the way to a more efficient use and redistribution of resources, but for this purpose much more statistical data of a kind not normally provided by existing meteorological services was required. Four speakers dealt with different aspects of this problem: Mr S. Gregory reviewed British rainfall data and suggested new lines of research; Mr G. Melvyn Howe applied Thornthwaite's method of assessing water need to England and Wales; Professor B. J. Garnier gave an extremely lucid account of the use of evapo-transpirometers to estimate irrigation requirements in Nigeria, and Mr J. L. H. Sibbons briefly reviewed existing methods of calculating evapo-transpiration and his suggested extension of these methods aroused much interest. In discussion Mr F. H. W. Green commented that existing formulas applied in Rothiemurchus had seriously underestimated moisture need in the dry summer of 1955. The specific problem of the relation between house heating and climate was examined by Professor Gordon Manley in an important and entertaining paper in which he showed that a long cool season imposes a greater strain on fuel resources than a short, severe winter; and by Mr M. Parry who considered differences in heating requirements consequent upon differences of site and local climate. Dr Alice Garnett also made significant reference to the siting of houses and schools in an interim report on an investigation

of the extent and causes of abnormal concentrations of atmospheric pollution within a city such as Sheffield. Miss E. M. Frisby reported on the use of climatological data in the planning of industrial projects in the U.S.A.

A morning session on social and economic geography was unfortunately timed to coincide with a joint session of Sections C and E on Antarctic research in which Sir Raymond Priestley, President of the Association, and Dr V. E. Fuchs were the first speakers and Mr H. H. Lamb later reviewed the present state of our knowledge of Antarctic climates. The Section E audience was inevitably decimated during the first lecture, with the result that Dr G. Joan Fuller's carefully reasoned and most interesting account of the growth of Santa Barbara from its Spanish foundation to 1955 did not receive the attendance it merited. It is to be hoped that such clashes will be avoided on future occasions. After the interval, when Dr Harry Thorpe resumed with a detailed and scholarly sample study of colonisation and heath reclamation in the Alheden district of Jutland, many members had returned. In the concluding paper Mr Leslie Symons raised points of great interest concerning under-utilisation of hill and marginal land in Ulster but discussion was curtailed by the clock.

The British Commonwealth received separate attention at another session in which Mr R. W. Steel gave an exemplary account of the copper belt of Northern Rhodesia. Mr H. Bowen-Jones described and illustrated methods used by the Durham University Department of Geography in a survey of Malta. He stressed that the island's chief problem is sheer poverty, which can only be relieved by capital investment from outside. Mr K. R. Sealy considered the use of large-scale air photographs in land-use mapping with reference to Cyprus.

Geomorphology was for once Cinderella to a climatological ugly sister, being relegated to the last morning of the meeting, but was no less keenly supported. Concentration was called for when Miss G. E. Groom essayed a critical appraisal of the earlier work of Professor T. N. George in a highly compressed account of her own research on the raised beaches of South Wales. Her comparison of exact beach profiles with earlier schematic sections was illuminating and led to a conclusion that the wave-cut beaches and beach deposits of Gower are not necessarily contemporaneous. Mr R. S. Waters described a previously unrecognised valley type on Dartmoor—caricatured by Professor D. L. Linton as a 'string of sausages'—which he attributed to the discovery by erosion of differences within the granite. The value of accurate field observation and measurement was further demonstrated by Mr R. A. G. Savigear with reference to the evolution of slope forms in North Devon and Cornwall. In particular he drew attention to the existence of rectilinear slope segments in what appear, on superficial inspection, to be smoothly curved slopes.

The remaining papers and excursions were preoccupied with local geography. Professor D. L. Linton stressed the significance of a situation astride the boundary of upland and lowland Britain in the interpretation of landforms and settlement within the region, a theme developed more fully with respect to Sheffield itself by Mr A. J. Hunt, and with reference to the extension of cultivation and enclosure into the East Moor of north Derbyshire by Dr S. R. Eyre. Historical aspects were considered by Mr I. S. Maxwell, who reconstructed the eleventh-century landscape from Domesday records, and by Dr H. C. K. Henderson who examined agricultural distributions in Derbyshire in the early nineteenth century. The fight to conserve what remains of the scenic heritage of the Peak District after a millennium of exploitation, by the establishment of one of Britain's first national parks, formed the subject of a well-illustrated contribution from Miss J. V. Aucott.

It was appropriate that suitable weather conditions should provide the background for a climatologically orientated Section E. So it befell that August closed with an exceptional total precipitation, and members were enabled to savour regional characteristics under contrasting conditions, for Saturday's excursions enjoyed fair weather while those on Sunday took place in continuous rain. It would be misleading to suppose from this experience that Kinderscout is more habitable than the Low Peak of Derbyshire, the south Yorkshire coalfield less dismal than its counterpart in north Derbyshire, the breaching of the Ashover anticline accomplished with less rainfall than the excavation of the Don gorge, or the Lincolnshire Wolds more fruitful than Creswell Crags and the open fields of Laxton. The excursions to these areas, together with shorter ones to the upland margin west of Chesterfield and

around Sheffield, left no important part of the region unvisited. One unusual excursion was also organised by Mr R. A. G. Savigear and Mr R. S. Waters as a field demonstration of a technique in morphological mapping. This was a great success but provoked so much discussion that the excursion was beheaded within a short distance of the first break of slope encountered.

In concluding this report it is fitting to recall that the section dinner was held in the Hadfield Hall of the Cutlers' Hall, with Professor B. J. Garnier of Ibadan University College, Nigeria, and Dr Necdet Tuncdilek of the University of Istanbul as the guests of honour. The large proportion of younger members was especially welcomed by the President of the Section, who reminded them that the responsibility for making future meetings as successful as this and previous meetings would be theirs.

A. J. HUNT.

ROYAL SCOTTISH GEOGRAPHICAL SOCIETY

PROCEEDINGS

A MEETING OF COUNCIL was held on 16th October 1956.

ANNUAL GENERAL MEETING

THE ANNUAL GENERAL MEETING was held in the Society's Rooms in Edinburgh on 9th October, with the President in the Chair. The President reported that the present membership of 3,137 was the highest in the history of the Society.

The Annual Report of the Council and the Financial Statement were unanimously adopted. The President thanked the retiring members, and the following were elected :

Vice-President : Miss Isobel W. Hutchison, LL.D., F.R.S.G.S.

Members of Council : Mrs K. L. Addison-Smith ; Alexander Douglas ; Ian R. Grant ; Robert Ingles ; Robert Kerr ; Mrs A. F. C. Lamont ; Professor Sidney Newman ; Dr C. J. Robertson and A. Graham Service.

Chairman of Centres : *Glasgow :* Professor R. Miller ; *Dundee :* Miss I. A. Tyrie ; *Aberdeen :* Col. M. M. Cruickshank.

Treasurer : Mr A. F. Morse was appointed in succession to the late Mr Clapperton. The other Office-Bearers were re-appointed.

LECTURE SESSION, 1956-57

The following lectures were delivered :

EDINBURGH. *Usher Hall.*—Lt-General Sir John Bagot Glubb, K.C.B., C.M.G., D.S.O., O.B.E., M.C. (Glubb Pasha), on " The Jordan Desert and its Tribes," 18th October. Brigadier Martin Hotine, C.M.G., C.B.E., on " Mapping the Blue," 15th November.

Central Hall.—Isobel W. Hutchison, LL.D., F.R.S.G.S., on " Edinburgh to John o' Groats—a Stroll," 24th October. Mervyn Ellison, SC.D., F.R.S.E., on " Russia seen by a Scientist," 7th November. Alfred Slack, B.SC., on " Plant Discoveries in the Highlands of Scotland," 21st November (in place of Dr Maclagan Gorrie, who is abroad). Donald G. Moir, F.R.S.G.S., on " The 1956 Tour to Northern Italy," 29th November.

Society's Rooms.—'New Developments in the Commonwealth'—R. Maclagan Gorrie, D.SC., F.R.S.E., on " The Damodar Valley Scheme," 4th October. J. P. Gunn, M.A., B.SC., M.I.C.E., on " Pakistan and India—Irrigation Problems," 14th November.

GLASGOW. *St Andrew's Grand Hall.*—Lt-General Sir John Bagot Glubb, K.C.B., C.M.G., D.S.O., O.B.E., M.C. (Glubb Pasha), on " The Jordan Desert and its Tribes," 17th October. Brigadier Martin Hotine, C.M.G., C.B.E., on " Mapping the Blue," 14th November.

St Andrew's (Berkeley) Hall.—Isobel W. Hutchison, LL.D., F.R.S.G.S., on " Edinburgh to John o' Groats—a Stroll," 25th October. Miss Elizabeth Stark on " Scottish Women's Himalayan Expedition," 22nd November. Donald G. Moir, F.R.S.G.S., on " The 1956 Tour to Northern Italy," 28th November.

Philosophical Hall.—'Expert Opinion on the Highlands'—Sir Robert Urquhart (Chairman of the Crofters' Commission), on "Highland Problems from a New Angle," 8th November. Sir John Stirling of Fairbairn, K.T., on "Rural Economy in the Highlands," 28th November.

DUNDEE. *Queen's College Hall.*—George Lowe, O.B.E., on "The Trans-Antarctic Expedition, 1956-58," 16th October. Sir Clarmont Skrine, O.B.E., on "Iran Re-visited," 13th November.

ABERDEEN. *Y.M.C.A. Hall.*—George Lowe, O.B.E., on "The Trans-Antarctic Expedition, 1956-58," 15th October. Sir Clarmont Skrine, O.B.E., on 'Iran Re-visited," 12th November.

REPORT OF COUNCIL

SEVENTY-SECOND SESSION, 1955-1956

(For the year 1st May 1955 to 30th April 1956)

The Council have the honour to submit the following Report :—

MEMBERSHIP

The changes during the Session are as follows :—

On the Roll at 1st May 1955		2893
New Members		808
		3701
Deduct by Death	35	
„ Resignation	529	
		564
On the Roll at 30th April 1956		3137

The fluctuation in the different categories of Membership at the four centres of the Society is analysed thus :—

	April 1955	April 1956		April 1955	April 1956
Edinburgh.			*Glasgow.*		
Life	277	266	Life	31	31
Ordinary	1159	1208	Ordinary	730	945
Associate	43	40	Associate	2	3
Junior	70	50			
Corporate (Schools)	15	18	Corporate (Schools)	30	26
Aberdeen.			*Dundee.*		
Life	8	8	Life	6	3
Ordinary	315	321	Ordinary	81	87
Associate	1	1	Associate	1	1
Outside Area Members	108	113	*Honorary Members*	16	16

MEDAL AWARDS

The Livingstone Medal was awarded to Robert Charles Evans, F.R.C.S., "in recognition of his outstanding leadership of the Kanchenjunga Expedition, 1955."

The Mungo Park Medal was awarded to :—(*a*) George Christopher Band, "for Himalayan achievements—Everest and Kanchenjunga, 1953 and 1955"; (*b*) Thomas Dempster MacKinnon, "for mountaineering and exploration in the Himalayas, 1950-1955."

The Scottish Universities' Medals were awarded to :—Margaret Adderley, St. Andrews University ; Archibald Stewart Fraser, Aberdeen University ; William R. Dunn, Glasgow University ; Eric Morton Fraser, Edinburgh University.

Fellowship of the Society

The Diploma of Fellowship was conferred upon :—(*a*) John Gilbert, M.A., D.PHIL., "for distinction in works on historical geography and in the teaching of geography"; (*b*) Archibald Richard Burdon Haldane, D.LITT., W.S., "for work and publication on the Drove Roads of Scotland."

Tour to Austria and Yugoslavia

160 Members of the Society took part in a tour to Austria and Yugoslavia in the summer of 1955. Contact was made with the Geographical Society of Austria and a talk was given to the Geography Department of the Ljubljana University.

Meetings of the Society

The Society held fifty-three Meetings during the Session. In Edinburgh : eight Evening Lectures in the Usher Hall ; ten Afternoon Lectures and two Evening Lectures in the Central Hall, Tollcross ; two Geographical Discussions in the Society's Rooms.

In Glasgow : eight Evening Lectures in the St. Andrew's (Grand) Hall, six Afternoon Lectures and two Evening Lectures in the St. Andrew's (Berkeley) Hall, one Children's Hogmanay Film Show, one Lecture Luncheon, and one Annual Excursion.

In Aberdeen and Dundee there were six Evening Lectures. Lectures are currently listed in *The Scottish Geographical Magazine*.

The Scottish Geographical Magazine

Three issues, each of 64 pages, have appeared, with the usual number of halftones and line blocks. A smoother paper has been adopted to give crisper definition of both type and line. Editorial policy has been to publish not only articles dealing with original research but also scholarly expositions of subjects which should be of interest to lay members of the Society and which might provide material for school geography lessons. The Council gratefully acknowledge a grant towards the cost of production received from the Carnegie Trust, and a grant from the University of Wales towards illustrations. They also record their thanks to the contributors of original papers and of reviews of books. The receipt of current publications from authors and publishers is likewise much appreciated.

Library and Map Department

Additions to Library :—249 books, of which 146 were purchased ; 9 pamphlets ; 3700 maps and charts. A welcome addition is the autographed Vol. I and II of Shackleton's *The Heart of the Antarctic*, presented by Mr. A. B. MacDuff of Newton Mearns, Renfrewshire.

During the Session 6146 books, 78 slides and 22 film strips were issued to Members.

The Council thank those who have supported the Society with the presentation of books, maps, charts, lantern slides and films.

The Society's Representatives

The following Members were appointed to represent the Society on the bodies named :—

Bruce Memorial Prize Committee—James M. Wordie ; Patrick D. Baird.
Joint Committee for Anthropological Research and Training—Robert Kerr.
National Committee for Geography—Professor Andrew C. O'Dell.
National Trust for Scotland—John Bartholomew, M.C., M.A.
Permanent Committee on Geographical Names—John C. Bartholomew.
Scottish National Memorial to David Livingstone—Lt.-Col. John Johnston.
National Institute of Oceanography—Professor Ronald Miller.

Obituary

The Council regret to report the death of The Right Hon. Lord Elphinstone, K.T., LL.D., F.R.S.E., President of the Society from 1930 to 1934 and Vice-President from then onwards.